Volume 6 November, 1927 Number 11

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Published Monthly by the American Welding Society
33 West Thirty-ninth Street, New York

American Welding Society

OFFICERS FOR 1927-28

F. M. FARMER, *President*
J. H. EDWARDS, *Senior Vice-President*
C. A. MCCUNE, *Treasurer*
M. M. KELLY, *Secretary*

Divisional Vice-Presidents

R. L. BROWNE, New York & New England
A. M. CANDY, Middle Eastern
STUART PLUMLEY, Middle Western
L. R. SHEPHERD, Southern
G. O. WILSON, Pacific Coast

DIRECTORS

(Officers listed above are also members of the Board of Directors)

Term Expires 1928	*Term Expires* 1929	*Term Expires* 1930	*Section Representatives*
JAMES BURKE	C. A. ADAMS	J. J. CROWE	C. W. BATES
J. W. MEADOWCROFT	A. G. BISSELL	W. H. GIBB	J. C. BENNETT
H. A. WOOFTER	A. E. GAYNOR	H. S. SMITH	H. P. DOUD
S. W. MILLER	H. M. HOBART	W. C. SWIFT	H. D. KELLEY
E. H. EWERTZ	A. G. OEHLER		J. C. LINCOLN
			J. W. MORRISSEY
			D. H. DEYOE
			W. A. SLACK
			ROBERT SIEMER
			F. E. ROGERS

PAST-PRESIDENTS

C. A. ADAMS (1919-20)
J. H. DEPPELER (1920-21)
S. W. MILLER (1921-22)
C. A. MCCUNE (1922-23)
T. F. BARTON (1923-24)
E. H. EWERTZ (1924-25)
A. G. OEHLER (1925-26)

CHAIRMEN, STANDING COMMITTEES

Executive—F. M. FARMER
Finance—C. A. MCCUNE
Membership—A. G. BISSELL
By-Laws—A. M. CANDY
Meetings and Papers—P. W. SWAIN
Nomenclature—J. W. OWENS

W. SPRAGEN, *Editor, Journal*

American Bureau of Welding

(RESEARCH DEPARTMENT OF SOCIETY)

OFFICERS

C. A. ADAMS, *Director*
H. L. WHITTEMORE, *1st Vice-Director*
A. D. RISTEEN, *2nd Vice-Director*
WM. SPRAGEN, *Secretary*

CHAIRMEN, RESEARCH COMMITTEES

Welded Rail Joints—G. K. BURGESS
Structural Steel—J. H. EDWARDS
Welding Wire Specifications—C. A. MCCUNE
Pressure Vessels—E. H. EWERTZ

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Copyright 1927, by the American Welding Society,
33 West Thirty-ninth Street, New York

Subscription $10.00 per year to United States. $11.00 to Canada. Libraries $5.00.
Back numbers, per copy: Members, $0.50; Non members, $1.00.

The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Volume 6 **NOVEMBER, 1927** **Number 11**

TABLE OF CONTENTS

Society and Related Activities

Page

Welding and Riveting 3

Structural Steel Welding Research..... 4

Pressure Vessels 5

Section Activities 6

Employment Service Bulletin..... 7

Technical Papers, Items and Reports

Survey of Existing Test Data by Structural Steel Welding Committee of American Bureau of Welding 8

Welded Aircraft, by T. C. Fetherston..... 15

Pipe Lines for Natural Gas Are Checked by Government Engineers for Leakage, by T. C. Fetherston 28

Discussion Fall Meeting Papers of American Welding Society..... 29

Electric Welding in Maintenance, by J. E. Webster..... 88

Current Welding Literature..... 92

SECTION OFFICERS AND HEADQUARTERS

PHILADELPHIA

Engineers' Club, 1317 Spruce St., Philadelphia, Pa.

Chairman—R. D. Thomas, R. D. Thomas & Co.
Secretary—H. E. Hopkins, 709 W. Huntington St., Philadelphia, Pa.

CHICAGO

140 S. Dearborn Street, Chicago

Chairman—Ernest Lunn, Pullman Co.
Secretary—Stuart Plumley, Gas Products Assn.

PITTSBURGH

311 Ross Street

Chairman—W. W. Reddie, Westinghouse Elec. & Mfg. Co.
Secretary—G. H. Danforth, Jones & Laughlin Steel Corp.

NEW YORK

33 West Thirty-ninth Street, New York

Chairman—F. E. Rogers, Air Reduction Sales Co.
Secretary—A. F. Keogh, Sound Welding Company

NORTHERN NEW YORK

General Electric Co., Schenectady, N. Y.

Chairman—C. L. Ipsen, General Electric Co.
Secretary—F. M. Jefts, General Electric Co.

CLEVELAND

23 Center Street, Willoughby, Ohio

Chairman—A. F. Davis, Lincoln Electric Co., Cleveland
Secretary—O. J. Bornemann, Euclid Crane & Hoist Co., 23 Center Street, Willoughby, Ohio

SAN FRANCISCO

Park Ave. & Halleck, Emeryville, Cal.

Chairman—W. P. Brown, Brown Bros. Welding Co.
Secretary—H. W. Saunders, Air Reduction Sales Co.

LOS ANGELES

Higgins Building, Los Angeles

Chairman—S. Barton Brown, Barton Brown Engineering Corp.
Secretary—N. R. Shade, General Petroleum Corp.

BOSTON

Affiliated Technical Societies of Boston, 715 Tremont Temple, Boston

Chairman—M. A. Thompson, Boston & Maine R. R.
Secretary—H. N. Ewertz, Peterson & Neville, Inc.

WESTERN NEW YORK

500 Morgan Bldg., Buffalo, N. Y.

Chairman—Mark Wade, Sr., Oxweld Acetylene Company
Secretary—G. W. Swan, J. A. Roebling's Sons Company

DETROIT

5443-12th Street, Detroit, Mich.

Chairman—W. C. Sprau, Barnes Wire Fence Co.
Secretary—C. E. Phillips, 5443-12th Street, Detroit

PORTLAND

524 Oregon Building

Chairman—J. S. Beall, Beall Pipe & Tank Corp.
Secretary—Samuel Powell, United Metal Trades Association

CANADIAN

933 Bay Street, Toronto

Chairman—Fred H. Williams, Canadian National Railways
Secretary—Campbell Bradshaw, Managing Editor, Canadian Machinery and Manufacturing News.

AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 6 NOVEMBER, 1927 Number 11

WELDING AND RIVETING

(Engineering News-Record, Sept. 29, 1927)

Discussion of structural welding at the American Welding Society meeting at Detroit last week gave fresh evidence of the continued and increasing liveness of interest in this new art. Serious attention to its details on the part of structural men is only a year or two old, although brilliantly successful pioneer work dates considerably farther back. Welding, therefore, has been in the position of an unproved pioneer method, seeking introduction into a field where admirable and thoroughly dependable methods already exist—an undertaking of obvious difficulty. Yet consistent extension of welding to new types of structural work has been made from month to month in the past few years, and progress continues along the same lines with increasing momentum.

What the ultimate end of this development is to be cannot yet be foretold. This much has been made certain by now, however: There is no room to doubt that welding will stay in the structural field, and that it will have to be reckoned with permanently as part of the working equipment of the art.

A note sounded in the Detroit meeting by Joseph Matte, well known Detroit engineer, is significant in its application to the future of welding. He summarized his experience in applying welding to a large range of structural forms by the conclusion that welding will be found preferable to riveting in all cases where it offers some inherent advantage that is of value in the particular application proposed. Instances are: where joints must be tight; where maximum rigidity is sought; where it is desired to make an attachment to one side of a structural member without having access to the other side. These, of course, are illustrative cases only, and no doubt many others will develop as the actual use of welding is further extended.

Almost simultaneous with the meeting noted, there was a new instance of agitation against the noise of riveting hammers in city residential areas. We have previously noted earlier discussions of this subject. On the present occasion, an influential association of the property owners along a street of costly residences and apartments in New York City made public protest against the ceaseless daily din of riveting hammers and other construction tools, and asked the city authorities whether they could not eliminate or reduce the peace-destroying noise by regulation. One can easily appreciate their attitude, for even a day spent in proximity to a building operation where riveting is in process is a sore trial, and a month of it could make life seem hardly worth while. Yet in those progressive regions of a large city where active development of new buildings is in progress, the metallic drumming of the riveting hammer, near or far, is hardly ever silent. Welding presents the opportunity of eliminating the noise, and in this fact may lie one of the inherent advantages to which Mr. Matte referred. Even in the face of greater difficulty and cost, it may succeed in largely displacing riveting on city work because of its freedom from noise. When the public and its governmental authorities become less tolerant of noise than they now are, it is not inconceivable that they might prohibit riveting as an unwarranted breach of the peace, or so seriously restrict its use as to put it out of the running.

It is proper to bear in mind, however, that the remark quoted has wider application than to the question of welding. Every new method, process or device has to overcome the opposition of that which exists and which it would replace. It must overcome the initial handicap of question as to efficiency, dependability or cost, but in its very nature it will also possess characteristics and advantages which the older method does not possess. The natural development of its

field of application rests on proper use of these inherent advantages of the new method. The whole art is enriched by the innovation, and the ultimate relation of the new and the old is likely to be found in their supplementing each other rather than in competing. Just as a new transportation facility, competing with an existing one, largely creates its own traffic and supplements rather than destroys the old facility, so a new technical method usually develops those uses and benefits arising out of its own characteristics and makes the resources of the art so much greater. So the ultimate place of welding in the structural field may prove to depend upon the new character of its service rather than on competition with riveting, and the two processes may co-exist and cooperate, to the general advancement of the structural art.

STRUCTURAL STEEL WELDING RESEARCH

Origin

A little less than a year ago with the aid of the American Institute of Steel Construction, a research committee was organized under the auspices of the American Bureau of Welding, known as the Structural Steel Welding Committee. The committee was made thoroughly representative of the entire industry and included structural steel fabricators, structural designers, welding experts and testing experts. Mr. J. H. Edwards, Chief Engineer of the American Bridge Company, was selected as chairman.

Purpose of Committee

As outlined at its first meeting, the stated purpose of the committee was to secure fundamental design data showing the ultimate or breaking strength of joints of a type suited to structural steel work when welded under uniform conditions by any available process and to take these unit strengths in certain important joints to note the behavior of the structure as a whole. All test specimens were designed to yield test data which could be translated into units per linear inch of weld. With such data the structural steel designer will be in a position to apply a suitable factor of safety, and to thus arrive at working stresses applicable to whatever unit dimensions of weld may be appropriate.

Division of Work

In order to properly subdivide the work, suitable subcommittees were appointed as follows: (1) A subcommittee under the chairmanship of Mr. F. T. Llewellyn, on Literature, to carefully review existing data which would be used as a basis for designing test specimens to yield needed information and which would give to the industry a critical digest of existing information. (2) A subcommittee on Tests, under the chairmanship of Mr. L. H. Miller. This committee was charged with the function of preparing specifications for test specimens which would yield the data needed by structural designers. (3) A Procedure Specifications Committee, under the chairmanship of Mr. F. M. Farmer, to prepare detailed instructions for the preparation and welding of the test specimens, the selection of the welders and inspection in order to insure a uniformity of results and to acquaint structural steel fabricators with the best existing information as to current practice. (4) A subcommittee on Ways and Means, under the chairmanship of Mr. E. H. Ewertz, to solicit the necessary funds and materials.

PROGRESS MADE

Review of Literature

This subcommittee immediately went to work in collecting and digesting existing information and as a result of their efforts a report has been submitted and approved by the main committee. This report is being published in this issue of the JOURNAL.

Tests Program and Procedure Specifications

A detailed program of tests was prepared by the committee, carefully reviewed and modified and procedure instructions prepared giving detailed information as to the qualifications of welders; method of preparing test specimens, procedure to be followed in welding each specimen and procedure to be followed in making tests of each specimen. In order to check these several specifications a series of pilot tests were made through the courtesy of the University of Toronto under the supervision of Professor Peter Gillespie. The results of these pilot tests were used by the committee in revising their main program.

Steel for Specimens

All the steel needed for the national program will be contributed

without charge to the committee by the United States Steel Corporation and the Bethlehem Steel Company.

Fabrication of Specimens

Through the courtesy of the American Institute of Steel Construction, a questionnaire was sent out to a number of structural fabricating companies soliciting their interest and assistance in the work of the committee. A number of fabricating companies have indicated a willingness to cooperate in this work and a questionnaire letter has been prepared and sent out by the chairman to secure information which will result in the selection of a representative group of fabricating companies, distributed geographically, who will prepare the specimens in accordance with the specifications of the committee.

Testing of Specimens

It is planned to secure the assistance of a number of universities and testing laboratories, including the Bureau of Standards, to make physical and other tests on the specimens prepared by the fabricating companies.

PRESSURE VESSELS

When the preparation of the Code for Unfired Pressure Vessels came up for consideration, the American Society of Mechanical Engineers' Boiler Code Committee were confronted by a mass of evidence, some of which was more or less conflicting. This led the American Bureau of Welding, about four years ago, to inaugurate a series of investigations on a number of tanks to secure reliable and authentic test data which could be used by designing engineers and by the Boiler Code Committee. Due to the limited cooperation offered by manufacturers and others it was only possible to test a few types of joints.

In order to extend their rules to cover other types of construction, the Boiler Code Committee need further scientific data and, accordingly, a joint Pressure Vessel Committee has been organized under the auspices of the American Society of Mechanical Engineers and the American Bureau of Welding.

A large representative committee was appointed, including welding, riveting and brazing experts, tank manufacturers, insurance representatives, testing engineers, metallurgists and representatives from the Boiler Code Committee.

A program was prepared which would yield, in the opinion of the subcommittee, the type of information desired by the Boiler Code Committee. This program includes the testing of a large number of tanks to destruction, breathing test of tanks, fatigue test of fabricated specimens and a study of the effect of heat of welding on the adjacent metal. This program was submitted to manufacturers and others and revised and is now receiving the consideration of the Boiler Code Committee.

Another subcommittee is at work preparing detailed procedure specifications to be followed in the preparation of the test specimens, the tanks, qualifying the welders, inspection and recording of test data. As soon as this is completed tank manufacturers will be asked to cooperate by furnishing the necessary specimens and tanks.

RAYMOND S. HOFFMAN PROMOTED

Mr. R. S. Hoffman, a member of the Society, has been promoted from the position of superintendent of shops at the Bayway Refinery to the position of mechanical superintendent of the refinery of the Standard Oil Company, Elizabeth, N. J. In his new position he will supervise all new construction work throughout the refinery, all maintenance and repair work in addition to his former duties as superintendent of shops. This work includes all welding and cutting operations.

ROBERT E. KINKEAD

Robert E. Kinkead has resigned as chief engineer, Welder Division of The Lincoln Electric Co. of Cleveland, Ohio, to engage in consuling engineering in connection with electric arc welding. Mr. Kinkead's office is located at 3030 Euclid Avenue, Cleveland, Ohio.

Starting early in the development of welding, Mr. Kinkead has become widely known among users of the arc welding process through his fourteen years of engineering work in the field. Upon graduation as a mechanical engineer, in electrical engineer-

ing, from Ohio State in 1913, he immediately joined The Lincoln Electric Co. In this capacity he served until 1917 when commissioned in the U. S. Navy. After the war he became chief engineer for The Mitchell Co., Chicago, emergency master mechanics and welding contractors. After a short period as welding expert for The Western Electric Co. at the Hawthorne Plant in Chicago, he returned to The Lincoln Electric Co. as chief engineer, Welder Division. In this capacity he has acted as consultant to the many users of welding and has written a number of technical papers for trade publications.

Mr. Kinkead is a member of The Cleveland Engineering Society and The American Welding Society.

SECTION ACTIVITIES

Boston

The Boston Section held a meeting on Oct. 21. The speaker of the evening was Paul B. Covey, Manchecter Engineering & Welding Co. Mr. Covey spoke on "Electric Welding of Structural Steel and Ornamental Iron." The paper was illustrated by slides.

On Dec. 14 the Affiliated Technical Societies of Boston will hold their Annual Meeting and have taken as their subject "Welding." This will be an all day meeting. Papers will be divided as follows: (1) Structural Welding; (2) Pipe Welding, including water, gas and steam pipes; (3) Industrial Welding and Cutting of Material. The program is being made up at the present time and it should result in a large meeting with all branches of the engineering profession in attendance.

Buffalo

The Engineering Society of Buffalo and Affiliated Sections made an inspection trip to the plants of The Federal Portland Cement Company and The Great Lakes Portland Cement Co. on Oct. 22. This trip was well attended and proved exceedingly interesting.

Chicago

On Oct. 7 the Chicago Section held an exceedingly successful meeting. There were about sixty present. The meeting started promptly at 7:30 by showing the Westinghouse pictures entitled "Electrified Travelogue." These pictures seemed to be of much interest and after they were shown Mr. C. J. Holslag of the Electric Arc Cutting & Welding Company addressed the meeting on the subject "Structural Welding." He showed many interesting lantern slides illustrating work which had been done in the welding of structural shapes, particularly the fabricating of a steel frame house in a suburb adjacent to Newark. After the talk there was a very lively discussion which continued for more than a half hour.

On Nov. 4 the Chicago Section will hold its November meeting. The first two reels of "The Story of Steel" will be shown. The speaker of the evening will be Mr. W. A. Becker of the Haynes Stellite Company, who will address the Section on "Stelliting of Metal Parts for Resistance to Abrasive Wear." This meeting will start at 7:30 p. m. in the rooms of the Western Society of Engineers, 1735 Monadnock Building, 330 S. Dearborn Street, Chicago.

The Chicago Section members have been invited to attend all or any sessions of the International Acetylene Association Convention to be held at the Stevens Hotel, Chicago, Nov. 16, 17 and 18.

Cleveland

The first Fall Meeting of the Cleveland Section was held in the Engineering Rooms, Carnegie Hall, on Oct. 27. Mr. J. F. Lincoln presented an interesting talk on "Arc Welding as a Manufacturing Tool." A series of highly interesting slides were shown with the talk.

The November meeting will be held on Thursday, Nov. 10.

Los Angeles

On Sept. 29 the Los Angeles Section arranged an inspection trip through the plants of the Columbia Steel Corporation. Over 100 men were present. This meeting was very instructive. Members of the Section and guests saw the furnaces and mill in operation.

New York

On Oct. 19 the New York Section held its October meeting. An educa-

tional movie film entitled "The Arteries of Industry" was shown. The speakers of the evening were Mr. W. G. King, director, Safety Division, American Optical Company, and Mr. T. A. Walsh, safety engineer of the American Optical Company, who spoke on "Eye Protection in the Welding Industry." Mr. King presented results of theoretical studies of this subject and Mr. Walsh discussed the practical applications of these theories as involved in actual electric and gas welding operations.

Western New York

The Western New York Section held its October meeting on the 20th. Mr. Frank P. Schmitkons, welding engineer, Curtiss Aeroplane & Motor Company, spoke on "The Welding of Aircraft Products." Samples of various parts that have been welded, both carbon steel and chrome-molybdenum, were shown.

Philadelphia

The regular monthly meeting of the Philadelphia Section was held on Oct. 17. Prof. H. L. Whittemore of the Bureau of Standards, addressed the meeting on "What the Bureau is Doing in Reference to Welding."

San Francisco

The San Francisco Section resumed the regular monthly meetings following the usual summer vacation period on Oct. 21. A paper describing the erection of the electric welded automotive shops for the Associated Oil Co. in Emeryville, was read by Mr. J. C. Bennett, Automotive Engineer of the Associated Oil Co. The designers of the building showed lantern slides of the features and advantages of this type of construction. A moving picture was also shown of the pipe line now being installed for the Feather River Power Co., by Brown Brothers Welding Co.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

SERVICES AVAILABLE

A-65. Oxy-Acetylene Welder desires position. Have had eleven years' experience in oxy-acetylene welding. Was six years with the National Chain Co. At this plant had full charge of the welding and lead burning. There were forty buildings with all kinds of machinery to be cared for. For the past five years have been employed by the B. M. T. Corp. as senior oxy-acetylene welder. Am very much interested in welding.

A-66. Electric Welder desires position. Have had ten years' experience on tanks, shipyard repair, locomotive repair, structural steel, power plant, (water-dam), automobile repair and job shop.

A-67. Welder desires position. Have had thirteen years' experience. Have been with N. Y. Engineering Company, Welding Engineers, Inc., and Electric Welder Co. of America.

Survey of Existing Test Data by Structural Steel Welding Committee of American Bureau of Welding

NEEDS OF FUNDAMENTAL TESTS ON STRUCTURAL WELDED JOINTS

Purpose. The purpose of the proposed tests is to secure data showing the ultimate or breaking strength of joints, of a type suited to structural steel work, when welded under uniform conditions by any available process, gas or electric. In the case of important Tee joints special specimens are recommended as a check on the simpler fundamental tests. While all the proposed tests are believed suitable for either process, a few specimens are designed to determine the characteristics of certain forms of weld specially suited to the gas process.

All test results should be capable of being translated into units per linear inch of weld, per square inch of welded contact surface, per square inch of the product of throat and length of weld, or per pound of welding wire.

With such data the structural steel designer will be in position to apply a suitable factor of safety, and to thus arrive at working stresses applicable to whatever unit dimensions of weld may be appropriate. The factor of safety to be used should depend on the extent to which minimum and maximum values in the specimens tested vary from their average.

Need—Tension. There have already been made a large number of tensile tests on specimens designed to ensure that the weld will outpull the base metal. In the case of butt joints on metal of moderate thickness these tests indicate very convincingly that a properly made weld, extending continuously across the full width of the specimen, may be expected to outpull the base metal. The question as to what would be the strength of intermittent butt-welds, or of welds extending only partially across the width of the specimen, is one on which previous test records are meager.

This question is important in connection with structural design, for steel framework differs from pressure vessels, for example, in that there are many structural cases where the full tensile strength of a member need not be developed. Such cases occur when the member is used in compression, or in flexure, or is kept to a certain size for reasons of clearance or symmetry. To weld clear across the full width of such members would involve the extra cost of many unnecessary inches of weld, which it is desirable to save. As the structural designer should know to what extent he can safely reduce the length of such welds, specimens

designed to give that information are recommended. Some of the specimens proposed by the committee would probably fail outside the weld, and it is therefore proposed to supplement these cases by specimens 8 and 12 in. wide, with intermittent welds designed to fail in the weld, and thus afford data as to their unit strength.

Regarding butt joints, it is also desired to know what range of thickness of base metal are best suited to various forms of weld, and specimens aimed to develop this feature are included in the program.

Need—Shear. Shear is probably the most important kind of stress in structural joints. Existing data regarding the ultimate shearing strength of fillet welds, when the pull is either normal or parallel to the weld length, and if butt welds when pull is parallel to the weld length, are very meager.

Fillet weld records should be supplemented by additional tests. A few tests have been made on fillet welds in parallel shear, but no record has been found of tests on butt joints in parallel shear. They apply to structural practice in many ways. Thus, if a diagonal member is to be connected at an angle with a main member by means of an edge to edge joint, the resultant strain can be resolved into two components, one normal and one parallel to the weld length. The unit value of the normal component can be determined from the butt joint tests outlined by the Committee. The corresponding value of the parallel component will be determinable from the proposed edge to edge tests. If these two unit values do not differ very much, respective factors of safety can be applied that will give a uniform working stress for both directions of strain, thereby simplifying the actual design of diagonal joints.

Parallel Tee.—In built up structural members of I, H, or T shape, the edge of one element must be jointed to the face of another element in such a way as to transmit longitudinal shear. A frequent case is the connection of web to flange in a girder or column.

Normal Tee.—When beams or girders act, for example, as wind bracing their connection to columns must transmit determinable moments of stress. It may be found that unit values based on the fundamental tests would apply here also, but the importance of this special class of joint warrants at least a check on these values.

Compression.—It is not considered necessary to make any compression tests, for analogy indicates that the strength of a joint in *simple* compression and in tension must be the same. This is confirmed as to welded joints by the University of Melbourne tests reported on page 34 of the January, 1927, Journal of the American Welding Society. The reason why the welded joint of a specimen tested in compression may seem to be weaker than a similar joint in tension is doubtless due to the fact that a compression specimen when tested to destruction always fails by sidewise deflection, never

by crushing, and this sidewise deflection adds a bending leverage to the direct stress.

In good structural design a compression member should never be used under a stress that is sufficient to cause appreciable sidewise deflection. The bending leverage on the joint of a tested specimen is therefore never reproduced in actual practice, and may be disregarded. Tension values can safely be applied to such joints.

Standard Bead.—Specimens involving fundamental data are designed in two ways. First, fillets are specified with dimensions of the legs equal to the thickness of the base metal. These are supplemented, by specimens with fillets uniformly with 3/8 inch legs, regardless of metal thickness, the length of such fillets varying with the computed stress.

Great emphasis is laid on these uniform size, or standard, fillet tests, for it is believed the structural industry will desire to standardize on size of legs of fillet in the same way it now standardizes on diameter of rivet.

The 3/8 inch size is suggested as a standard because it is understood that size is about the largest fillet it is commercially practicable to deposit in single layer with a standard size of welding wire. Moreover, both the volume and cost of larger fillets increase much more rapidly than their strength. On the other hand, it is feared that a fillet much smaller than 3/8 inch would give insufficient contact surface, especially in the case of joints involving any clearance between the base metal parts.

Width of Bars.—In addition to "B" bars, 3 and 4 inches wide, it is recommended that for several types of joint bars 8 and 12 inches wide be tested with welds both continuous and intermittent. The purpose is to ascertain whether the unit strength of welds of different lengths varies enough to matter.

Grades of Steel.—It is not recommended that the entire range of tests be applied to more than one grade of steel as base metal, for the reason that the proposed tests are intended to determine only the unit strength of welded joints. Therefore, a few tests may be provided to ascertain if the base metal is such as will permit of satisfactory fusion and the relative strength of welds as compared to ordinary structural steel.

The grade of steel contemplated for the entire range of tests is specified below. In addition it is suggested that the mills furnishing the material be advised of our desire to learn the weldability of other special grades of steel, such as high carbon steel, copper steel, and silicon steel, and that they be asked to furnish a few bars of these special grades in whichever of our specified sizes it is convenient to do so. We can then apply these bars to whatever joint specimens they will suit, and compare the results with those on standard grade steel.

Basis of Specimen Design.—In designing specimens to develop the foregoing features, the following rules were observed:

(1) As few as possible different widths of bar are specified, in order to facilitate the securing of a uniform grade of material from the mills.

(2) Thicknesses of "B" bars vary by ⅛ inch, and range from ¼ to ¾ inch except in the case of butt joints which go up to one inch.

(3) Base metal to be Open Hearth Structural Steel for Builders in accordance with the latest A. S. T. M. Specification A-9. The ultimate strength of this grade of steel ranges from 55 to 65 kips per square inch.

(4) In computing the probable minimum breaking strength of "B" bars, use their area multiplied by 55 kips.

(5) As far as practicable the section modulus of "C" bars is 50 per cent greater than that of the "B" bars in question. This is for the purpose of minimizing the effect of eccentric pull in the testing machine.

(6) In computing the probable maximum breaking strength of the weld, the highest comparable unit strength in any previous recorded tests is used. Where none is applicable, pilot tests to be awaited.

The length of weld is then dimensioned so as to make (4) at least 20 per cent greater than (6). It is believed these proportions will in all cases insure a break in the weld rather than in the base metal.

Submitted by F. T. Llewellyn at meeting of Structural Welding Committee in Philadelphia, February, 1927, in explanation of detailed sketches and tables of proposed tests submitted by *Subcommittee on Test Specimens*, L. H. Miller, Chairman.

REPORT OF COMMITTEE ON SURVEY OF EXISTING DATA

PREFACE

The aim of the Sub-Committee on Survey of Existing Test Data has been to assemble in the following tables such published information as relates to the unit strength of welded joints. A bibliography contains a list of data which did not lend themselves to easy tabulation.

Direct comparison of results is difficult due to a lack of uniformity in preparing the specimens and recording the test data.

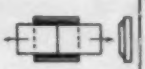
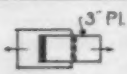
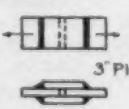
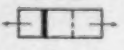
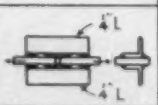
All of the items were produced by the Arc Process except Reference Nos. 18, 24 and parts of 27, 28 and 30, in which the Gas Process was used; and Reference 31, in which the Resistance Process was used.

standard grade steel.

BIBLIOGRAPHY

Ref. No.	Reported by	Description
24	H. H. Moss, A. W. S. Journal, October, 1926	Fink roof trusses, 40-ft. span, ¼ pitch, 8 panels, 1 riveted, 3 welded, 1 tubular construction, top chords failed in all tests with comparative strengths as follows: riveted 100%, welded 114%, tubular 99%.
25	A. M. Candy, A. W. S. Journal, October, 1926	Tests on beam connections to columns and on built up girders for both welded and riveted construction.

Fillet Welds

Ref. No.	Reported by	Specimen Sketch	No. tested	Welds Size Lgth.	Size Fil.	Ult. Strength lbs. per lin. in. Min.	Ult. Strength lbs. per lin. in. Aver.
1	H.E.Grove A.W.S.Journal Jan.1927.		18 12	1"to 6" 1"to 4"	5/16 5/16		1"=7500 6"=8100 1"=7250 4"=6658
2	Do.		18 6 4 3 5	.52-1 .51 Av. 1.59 Av. 1.55 1.15-156	9/64 3/16 1/4 5/16 5/16	3090	3630 4490 5680 5810 7870*
3	Do.		6 6	2 4	1/2 1/2		11841 10806
4	Do.		3 6	3 3	5/16 1/2		10610 15450*
5	Do.		3 6 6	3 3 3	3/16 1/4 5/16		9000 10290 13450*
6	R.A.Storm A.W.S.Journal Jan.1926		7 8 9 6	2 2 2 2	1/4 5/16 3/8 1/2	9650 9630 9680 14700	10540 11210 13040 16110
7	E.S.Humphreys Union Coll. Iron Age May 25,1922.		1	15" Total each side			7650
8	Do.		1 1 1	4 3 1	3/8x1/2 do. do.		9350 9690 11390
9	Do.		4 4 4 4 4	3 3 3 3 3	A 1/2 B 1/2 A 3/8 B 1/2 A 3/8 B 3/8 A 1/4 B 3/8 A 1/4 B 1/4		11880) 10930) 10000)* 8030) 7470)

* Double Run

Fillet Welds

Ref. No.	Reported by	Specimen Sketch	No. Tested	Weld Size Lgth.	Weld Size Fil.	Ult. Strength lbs. per lin. in. Min.	Ult. Strength lbs. per lin. in. Aver.
10	Am.Br.Co. Ambridge MMB.Oct.25/26	1½ & 2"	1	1-1/2	3/8		8020
			1	2	3/8		7350
11	De.	1½"	2	1-1/2	3/8	8060	8100
12	Am.Br.Co. MMB.1919/1920	1½ x ⅜ Pls.	9	1-1/2	3/8	3750	5130
13	Am.Br.Co. MMB.June 10/26	2½ x ½ Pls.	3	2-1/2	1/2	8690	10620
14	De.	2½ x ½ Pls.	2	2-1/2	1/2	14250	14610
15	De.	2½ x ½ Pls.	3	2-1/2	1/2	10870	12030
16	Emergency Fleet Corp Report on Elec.Weld. 1918 Report #7	Pls. 9" wide	3	9	1/4		6770
			3	9	5/16		8810
			3	9	3/4		17620
			3	9	1		23280

Butt Welds

Ref. No.	Reported by	Specimen Sketch	Thick Pls.	No. Tested.	Weld Ult. Strength lbs.per.lin.in. Min.	Weld Ult. Strength lbs.per.lin.in. Aver.
17	H.H.Grove A.W.S.Journal Jan.1927	Width not given	3/16	3		12000
			1/4	2		14400
			5/16	2		17650
			3/8	12		18955
18	H.H.Thum Linde Air Products Co. A.W.S. Journal Nov.1926.		Not Given	About 500	47000# / sq.in. Norway Iron Rod 58000# / sq.in. High Test Rod.	
19	Kobert A.I.M.E. Feb. 1919.	Specimens 1x8 cut from 8x8 pls. after welding	1/2	33	17100	25420
20	De	Size same as #19	1/2	11	23900	29410
21	Am.Bridge Co. MMB 1919-1920	1½ x ⅜ Pls.	3/8	7	14810	15710
22*	De	1½ x ⅜ Pls.	3/8	12	15260	18100
23	Am.Bridge Co. MMB.June 10/26	2½ x ½ Pls.	1/2	3	20850	21860
		2½ x ½ Pls.	1/2	3	24260	25030

* Test specimens were sheared to width after welding two wide plates together. (Compare with #21 where specimens were cut before welding.)

26	A. G. Bissell, A. W. S. Journal, September, 1926	Tests on welded beam connections. Also fatigue tests under repeated vibrations for welded and riveted beam connections.
27	Gen. Elect. Co., Emergency Fleet Corp. Report on Electric Welding, 1918	Report No. 17 gives a number of comparative tests on welding with G. E. arc welding, quasi method and the oxy-acetylene method.
28	A. W. S. Bulletin No. 5, June, 1923	This bulletin deals with the design, construction and tests of pressure vessels.
29	G. A. Caldwell Manuscript	This manuscript covers a test made on a bowstring truss by the Mississippi Valley Structural Steel Co. for A. C. Bradley, Springfield, Ill., Nov. 4, 1926.
30	E. H. Ewertz, A. W. S. Bulletin No. 6, February, 1924	Reports tests of joints for use in shipbuilding, some of which have a general application to structural steel welding.
31	H. A. Woofter, A. W. S. Journal, October, 1924	A paper on "Uses of Spot Welding in the Structural Field" which gives comparative figures for riveted and spot welded construction.
32	Soc. N. A. & M. E. Transactions, 1918. Discussion of paper by H. J. Cox	Tests show increase in strength of welds by use of higher amperage.

UNPUBLISHED DATA

Prof. Peter Gillespie, University of Toronto, Toronto, Canada.
Physical tests on metal in weld made by depositing the metal in a trough or a pad and then milling out test specimens.

American Welding Society.
Tensile tests on welded specimens made by the Perry Testing Laboratory at Detroit.

General Electric Company, Schenectady. N. Y.
A very carefully controlled set of tests on fillet welds, 1/4, 5/16 and 3/8 inch in size.

James W. Owens, N. N. S. & D. D. Co., Newport News, Va.
Tests on fillet welds.

American Bridge Company.
Tensile tests made in 1927 on lap, edge, Tee and plug welds.

F. B. Walker, Eastern Massachusetts Street Ry., Boston, Mass.
Test of specimen which was duplicate of one used for reinforcing a damaged diagonal in the Merrimac River Bridge.

Submitted by *Subcommittee on Survey of Existing Test Data*, F. T. Llewellyn, Chairman, at meeting of Structural Welding Committee in Detroit, September, 1927.

Welded Aircraft*

By T. C. FETHERSTON†

The New York *Sun* of Monday, July 18, 1927, in commenting editorially upon the welcome accorded to Commander Byrd and his associates on their recent trans-Atlantic flight, carried the following tribute to the engineers, designers and manufacturers of the air craft which have successfully stood the severe test of long distance flying:

"New York speaks for the nation in its welcome to the five aviators who have again demonstrated not only the fortitude and professional attainments of the men who are building the intricate

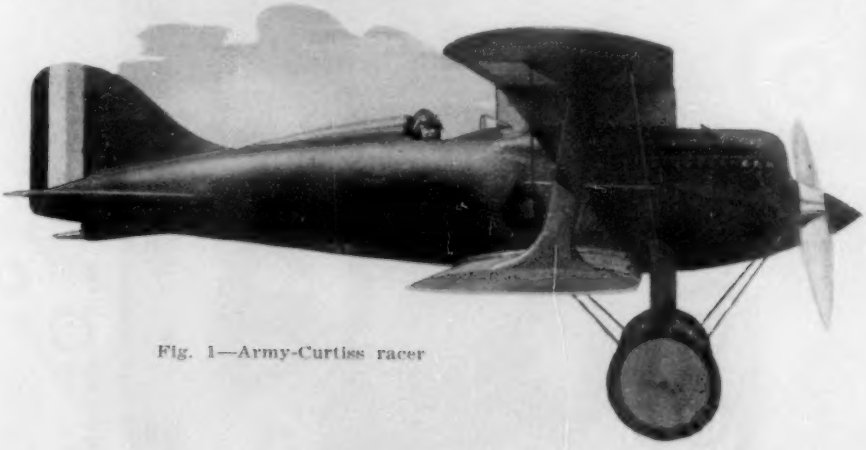


Fig. 1—Army-Curtiss racer

structure of a new transportation system, but who, under the most exacting conditions, have once more proved the stability and mechanical excellence of the planes which have been developed for their use. Willingness to undergo peril, resourcefulness, devotion to duty would not be less admirable or less admired if these qualities were expended under the handicap of less excellent planes, but they would be less effectively employed for advancement of the science of aerial navigation."

Now that the first excitement and the public appreciation of the splendid human qualities that have made possible these long distance flights have given way to the methodical study of the scientific facts involved, it becomes more and more apparent that the splendid heroism of Commander Byrd and his associates, Colonel Lindbergh, Chamberlin, and Levine, and Lieutenants Maitland and Hegenberger, could only have accomplished the fortunate results had their planes and motors been perfected to withstand the

*Paper appearing in September issue of "Oxy-Acetylene Tips."

†Manager, Technical Publicity Department, Linde Air Products Co.

tremendous stresses of sustained flight and the unusual stresses imposed by the heavy loads which they were all forced to carry.

Great appreciation has been shown the makers of the Wright Whirlwind type motor with which all of these planes were powered, but none the less appreciation is given to the several manufacturers of the planes themselves and to the design and construction methods that have made possible these sturdy and dependable craft.

In this connection it should be noted as an outstanding fact that

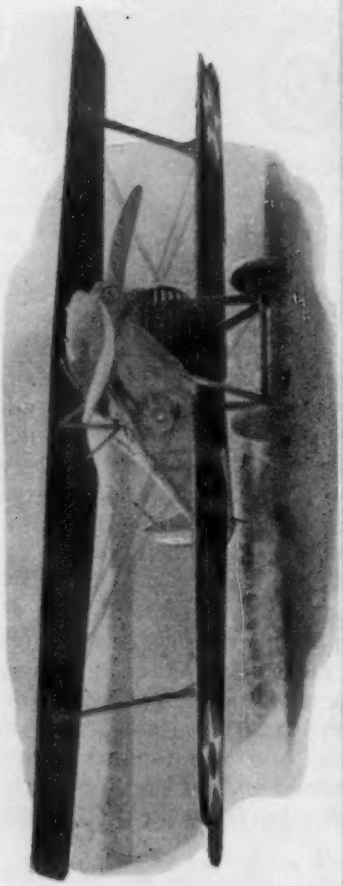


Fig. 2 (left)—Army pursuit plane

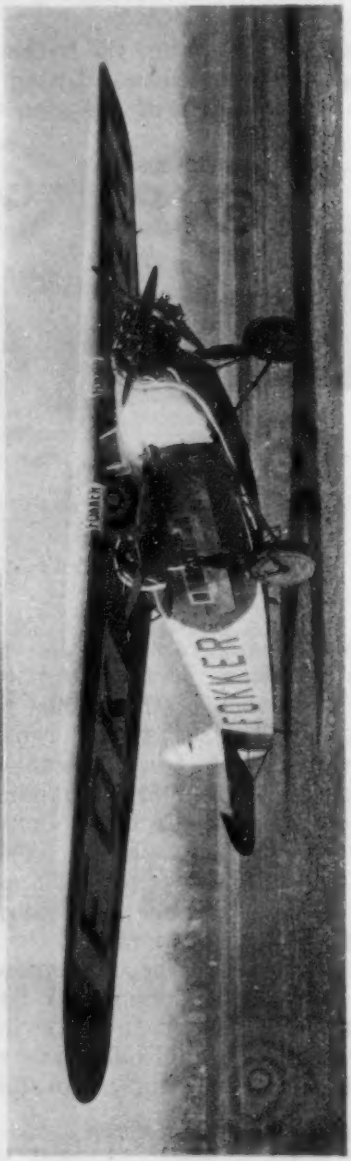


Fig. 3—Tri-motored Fokker plane

*Paper appearing in September issue of "Oxy-Acetylene Tips."
†Manager, Technical Publicity Department, Linde Air Products Co.

all of these overseas planes were built of steel tubing and were fabricated entirely by oxy-acetylene welding. The Ryan monoplane used by Col. Lindbergh was made by a California manufacturer who has shown every confidence in the oxy-acetylene process. The Columbia-Bellanca, used by Chamberlin and Levine, was built entirely of oxy-acetylene welded chrome-molybdenum tubing, and the Fokker planes used by Commander Byrd and Lieut.

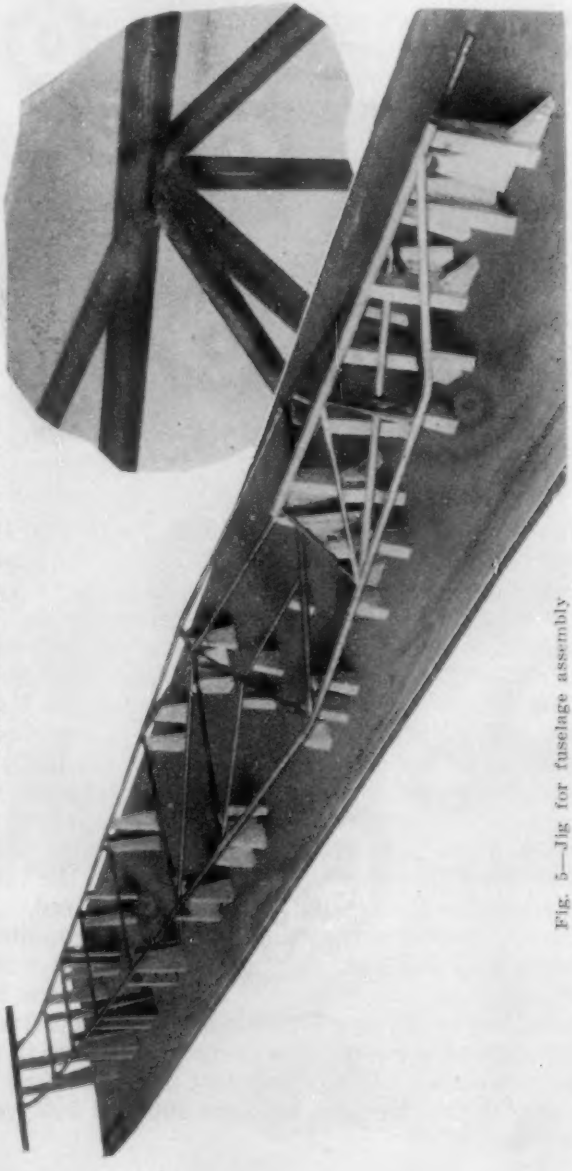


Fig. 4 (right)—Joint assembly before welding, held in place by tack-welds

Fig. 5—Jig for fuselage assembly

Maitland are all-welded, and of chrome-molybdenum and mild steel tubing.

Adoption of oxy-acetylene welding by the aircraft industry has been based on several important considerations. In the first place many tests carried on over long periods of time, made by both the army and navy aviation authorities and by civilian scientists, have proved that by welding, a joint of the maximum strength and minimum weight can readily be made under average production conditions. In the second place, the test of service both under normal and extraordinary conditions is an indication that these laboratory figures have been amply justified.

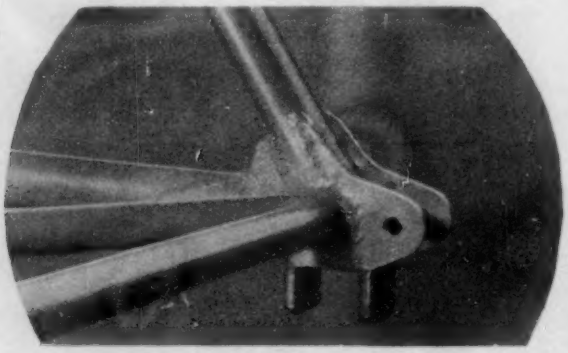


Fig. 6—Joint assembly after welding

In the June supplement of the United States Official Postal Guide there appears a report by Airmail Pilot Charles A. Lindbergh covering the northbound mail flight from St. Louis to Chicago on Nov. 3, 1926. During this flight it became necessary to abandon the plane at a height of 13,000 ft. The pilot's life was saved by his parachute. When the wreckage of the plane was discovered the next day it was found that even after this terrific fall the metal fuselage was still intact. To use the words of the report describing the condition of the plane: "The wings were badly splintered, but the tubular fuselage, although badly bent in places, had held its general form even in the mail pit." Photographs of the Fokker plane *America*, after its forced landing on the shores of the English Channel, also show that there was no collapse in the tubular metal fuselage even under the terrific strains encountered.

These results under extraordinarily severe conditions simply bear out the results obtained by hundreds of planes for thousands of miles of flying. Conversation with a number of the most prominent manufacturers of oxy-acetylene welded aircraft reveals that they have never had a report of a failure in service in any welded joint. The importance of this statement is emphasized by the fact that there are, on the average, between 400 and 500 welded joints in a single plane.

Studies of the welded joint for aircraft at the United States Army Air Service Field at Dayton, Ohio, outlined by J. B. Johnson before the International Acetylene Association in 1925, indicated very clearly that welded joints will stand not only the normal stresses of routine operation but also the serious shocks of forced landings. Mr. Johnson showed that in routine welding in chrome-molybdenum tubing, it was possible to attain an ultimate tensile

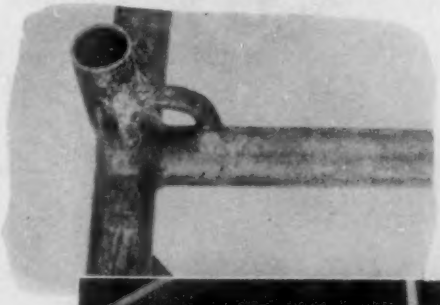


Fig. 8 (above)—Wire terminal made of bent segment of tubing at fuselage joint

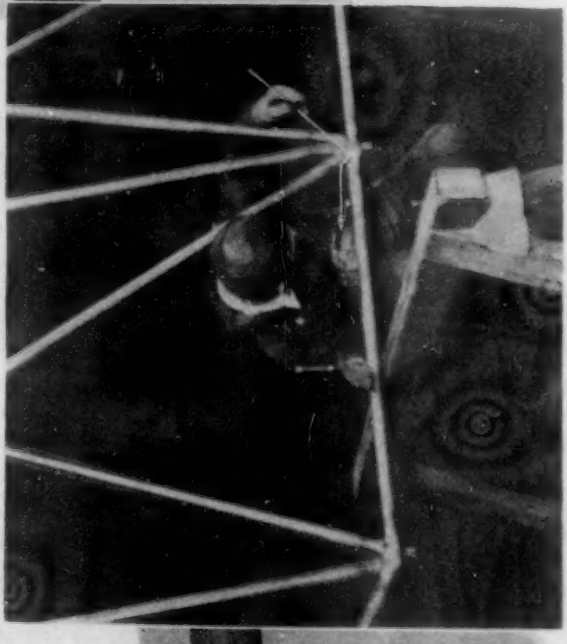


Fig. 9 (left)—Welder completes joint assembly

Fig. 7 (below)—Joint, showing stabilizer wire terminal

strength of 96,900 lb. The material had a specified minimum tensile strength of 95,000 lb. per square inch. In his description of the results of tests made under his direction, Mr. Johnson said, "All of the new designs of airplanes used by the United States Army, from the 2200-lb. racing airplane, to the large 12,000-lb. bomber, have the welded steel fuselage. This type of structure lends itself to quantity production as very little machinery is necessary, and with a skilled crew of welders structures can be turned out rapidly."

It is usual in welding chrome-molybdenum tubing in aircraft construction to use high test or mild steel welding rod. The only

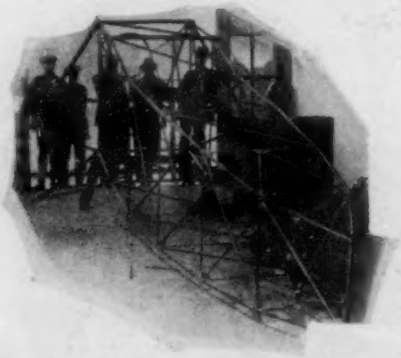


Fig. 10—One type of welded fuselage

advantage in using chrome-molybdenum rod, according to those who have investigated the subject, and have made tests on welded joints in aircraft tubing, appears to be where the final joint is to be heat-treated. This, however, does not seem to add greatly to the strength of the joint, and for all practical purposes, use of the high test or mild steel rod without heat treatment is amply sufficient. The heat of oxy-acetylene welding has very little effect upon tubing of the composition used, this fact being ascribed to the air-hardening properties of the alloy.

Some manufacturers of aircraft have so designed their structures that chrome-molybdenum tubing is used only for the members which act in tension. Mild steel tubing is used for compression members. This usually reduces the cost of the finished structure without reducing its strength or efficiency. Mild steel tubing is welded into chrome-molybdenum tubing in a complicated joint used in aircraft with entire satisfaction.

Oxy-acetylene welding has not only made possible a stronger and more dependable framework for air-craft, but also has simplified greatly the mechanical problems involved in aircraft construction. The welded joint comes nearest to the ideal structure. It eliminates fittings and other composite joints entirely, and makes the fuselage frame itself, in fact and in action, one single unit of

steel. The welded joint on planes of moderate size does away with several hundred pounds of cast fittings with the attendant decrease in the weight of the ship itself and proportionate increase in profitable load. Added to this is the fact that the welded joint will give remarkably high values in both tension and compression,

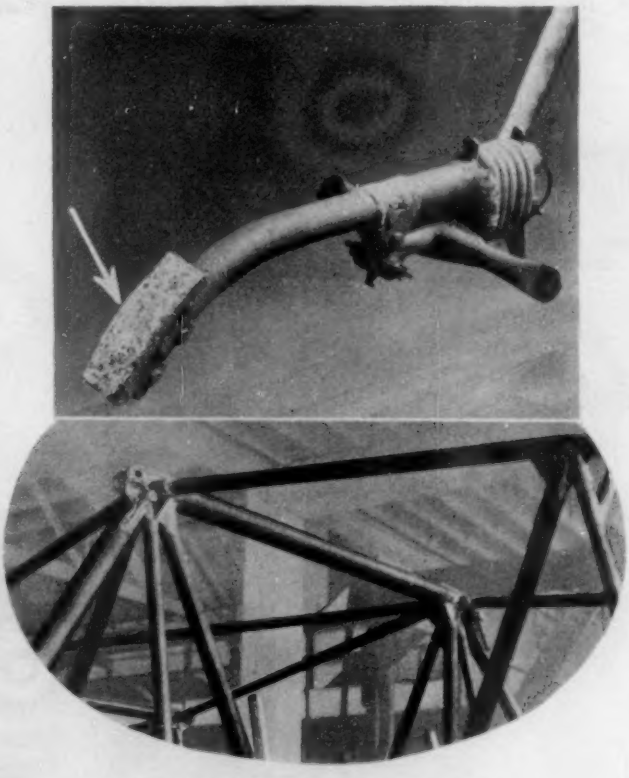


Fig. 11—Tail skid stellited to resist wear

Fig. 12—Welded planes in production at aircraft factory

far beyond those which can be attained under any condition with tubing of the same wall thickness or weight joined by any other method.

With cast fittings and metal tubing construction, or with wood members fabricated in any possible way, each joint represents a special job, and the fittings for each connection, however simple it

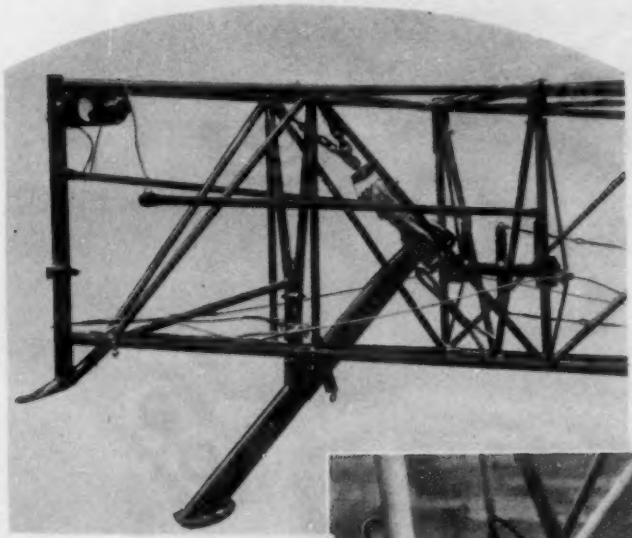


Fig. 14—Detail of tail control and skid construction

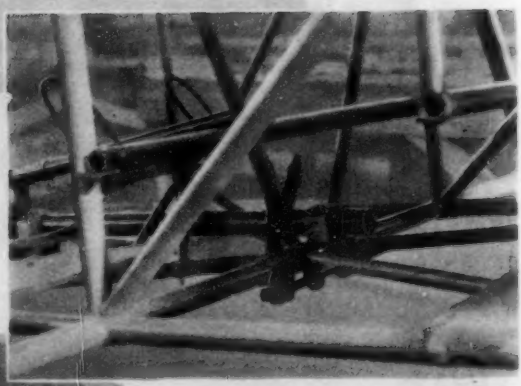


Fig. 15—Control cabin requires complicated joints

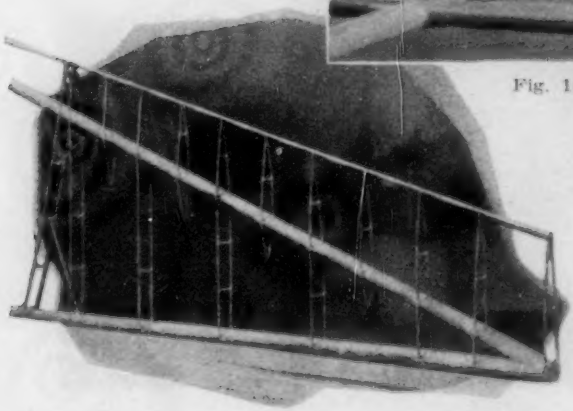


Fig. 16—Welded stabilizer

may be, must be designed and cast well in advance of the actual assembly of the fuselage. By welding, all this is eliminated. The tubing is simply cut to size and mitered at the end, if necessary, set up in an appropriate jig, and the joint welded. Two of the photographs accompany this article (Figs. 4 and 6) show in detail a complicated joint readily made by welding with tubing members attached at odd angles.

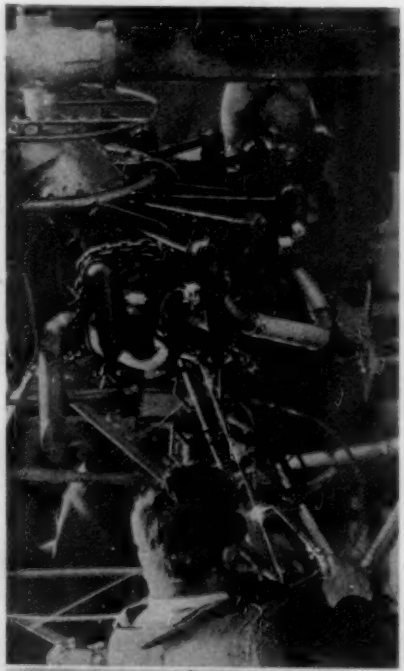


Fig. 18—Final joining of cockpit braces

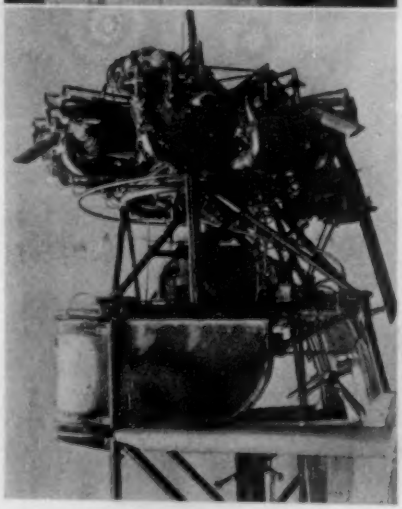
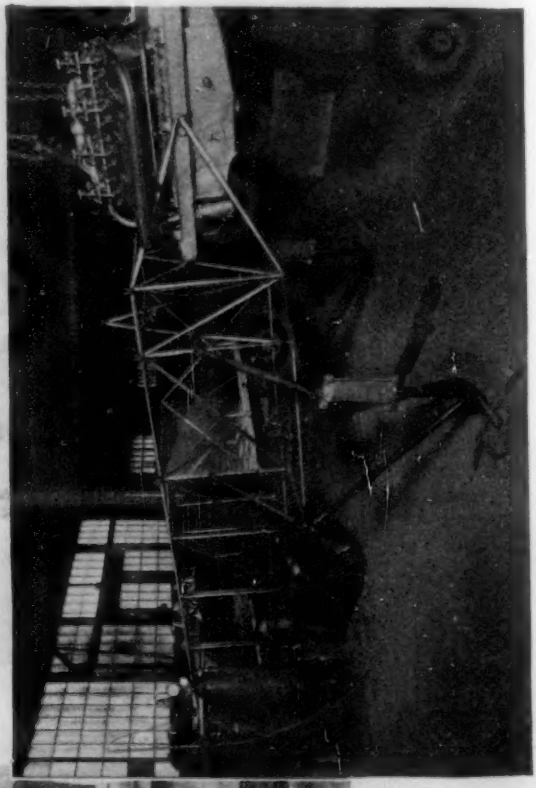


Fig. 17—Engine mount for Wright motor

When welding is employed, the matter of changing the design of the ship is a relatively minor one, because there are no patterns or castings to scrap. Where it becomes desirable to use tubing of a different diameter or wall thickness, the very adaptable process of welding can readily be employed without any change whatever in apparatus or method. Tubing can be bought in stock lengths, and it is not necessary to do any threading or fitting.



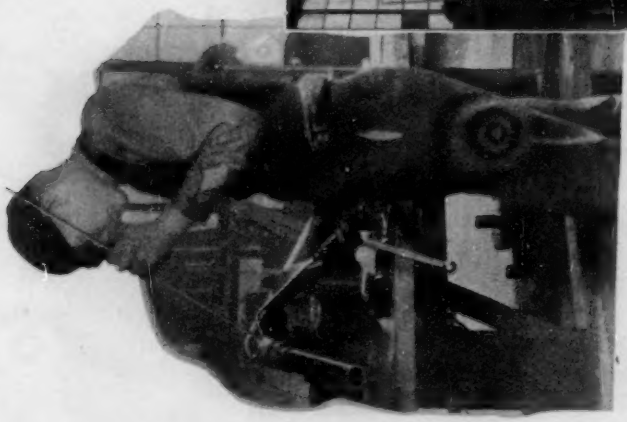


Fig. 19 (above)—Bronze-welding on mild steel tubing

Fig. 20 (right)—A final welding step

In certain types of planes, wire tie rods are used for some tension members. Where this method of construction is employed, lugs for attaching the wires at the joints are attached either by welding on a punched piece of plate, or by welding a short curved segment or rod or small diameter tubing across one angle of the joint. Wire terminals for the controls are also made in this way.

The engine mount, which varies often with the same type of

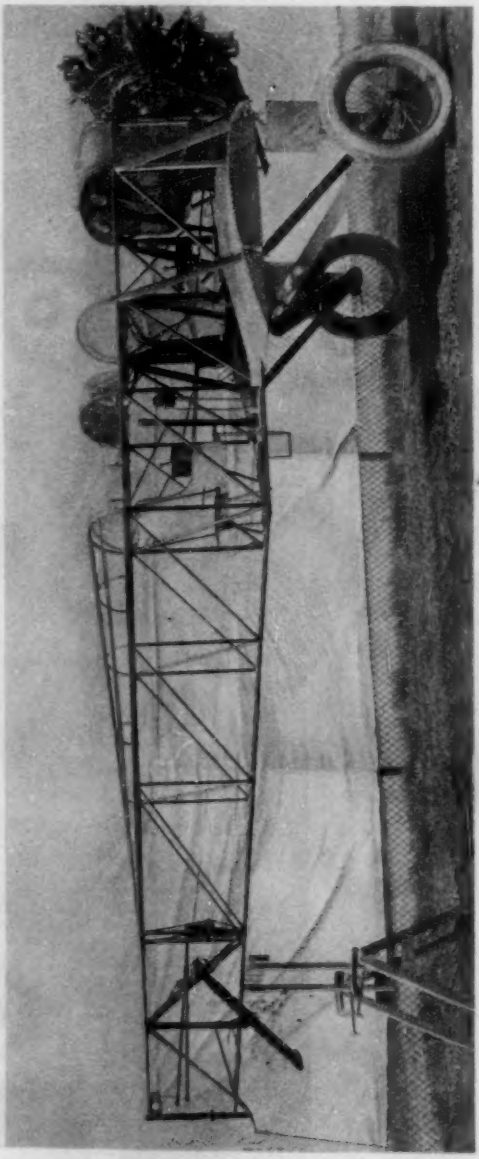


Fig. 21—All-welded fuselage, ready for covering and wings

plane for different types of motors, is universally built by welding. The joints in this structure take considerable stress in flight, but the oxy-acetylene process has been shown to be entirely suitable for making the large number of heavy-duty connections required.

Most of the joints in welded tubing fuselage are of the butt type. Some manufacturers of aircraft, however, use what they term a "fishtail joint" for certain types of construction, claiming that this throws bending stresses out of the weld itself and gives a stronger joint in compression.

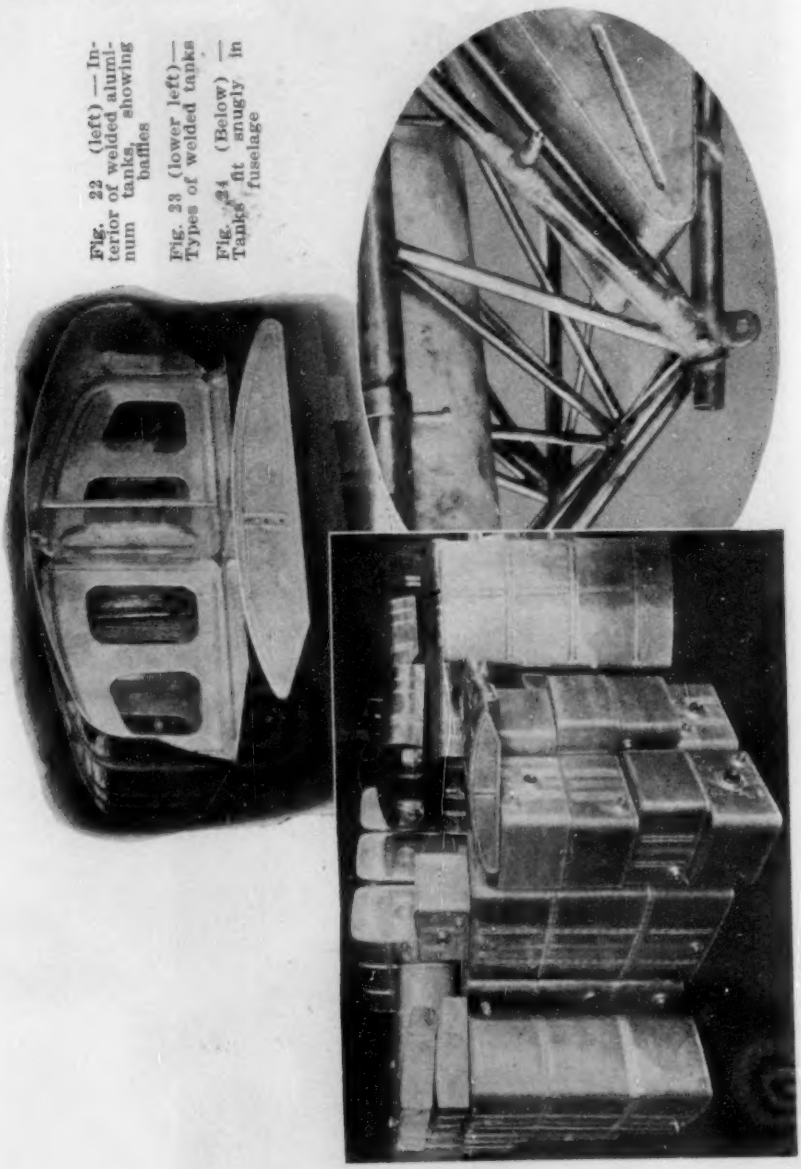


Fig. 22 (left) — Interior of welded aluminum tanks, showing baffles

Fig. 23 (lower left)— Types of welded tanks

Fig. 24 (Below) — Tanks fit snugly in fuselage

In addition to the joint in the tubing members, a large number of attachments and parts of the frame itself are either fabricated or attached to the fuselage by welding. These include dozens of parts, stamped from light gauge sheet steel in sections and welded together, and composite parts, made of stock sheet, bar and strip, together with small castings and forgings. In one plane, built in California, the tail skid is surfaced with Stellite to reduce wear (Fig. 11).

Most of the gasoline, oil and water tanks used in aircraft are oxy-acetylene welded from aluminum sheet. These tanks are built in a large number of intricate designs, many of them to fit in the wings and in odd shaped spaces in the fuselage. It is vitally necessary that the tanks be strong and tight. Many are equipped with perforated baffles to prevent excessive surging of the material in the tanks as the plane changes its course. These baffles are also welded in place, usually by pinning the baffle to the side of the tank with aluminum pins and then welding the projecting ends of these to the outside of the tank.

Several types of motors employ welding in one way or another as a production process. The Liberty motor is largely fabricated by welding together stamped parts of steel plate and sheet, and performed very satisfactorily indeed with regard to the service of the welded seams. Like most foundrymen, manufacturers of castings for aircraft motors often find it desirable to correct minor defects in the castings by welding. Such reclaimed castings are always as good, from a performance standpoint, as those perfect when originally poured, and often, because of the equalization of locked-up foundry stresses, are much better.

Intake and exhaust manifolds, exhaust tubing, water circulation tubing for water cooled motors, and many other minor attachments to the motor, are built by welding stamped parts of sheet steel. Some manufacturers employ bronze rod for this because they claim that this minimizes distortion in the tubing. Considerable copper tubing is also welded.

By giving the designer and builder of aircraft a thoroughly dependable method of construction, sufficiently flexible to keep pace with the rapidly changing and expanding industry, the oxy-acetylene process has contributed greatly to the development of the aircraft industry. All types of planes, from experimental machines of radical design to standard equipment of everyday production, are acetylene welded with uniformly splendid success.

Pipe Lines for Natural Gas Are Checked by Government Engineers for Leakage

T. C. FETHERSTON†

A recent report issued by the Bureau of Mines, shows important advantages for welded natural gas pipe lines over the screw-coupled and rubber-coupled joint types.

"The tests that have been run on welded lines show conclusively that this type of construction is preferable, as far as leakage is concerned," says the Circular No. 6010 by E. L. Rawlins.

To arrive at this conclusion, 26 lines were studied. Of these there were 11 screw-coupled lines, 9 rubber-coupled lines and 5 welded lines. Operating pressures in these lines varied from 165 to 300 lb. per sq. in. The lines were located in all parts of the country and varied widely in age of pipe, local conditions, terrain and temperature. The figures are given below:

LOSSES IN CU. FT. PER YEAR PER MILE, 3-IN. LINE AT 100-LB. GAUGE (USING EQUIVALENT MEASUREMENTS)

Screw-Coupled Lines			Rubber-Coupled Lines			Welded Joint Lines		
Line No.	Loss	Operating Pressure	Line No.	Loss	Operating Pressure	Line No.	Loss	Operating Pressure
1	4,916,000	165	12	7,450,000	260	21	625,000	165
2	4,299,000	165	13	825,000	260	22	58,000	290
3	2,581,000	165	14	1,400,000	260	23	17,000	165
4	15,100,000	160	15	961,000	260	24	512,000	290
5	1,625,000	130	16	800,000	270	25	75,000	280
6	686,000	230	17	400,000	140	26	630,000	300
7	660,000	170	18	3,400,000	210			
8	1,142,000	140	19	912,000	230	Total	1,917,000	1,470
9	1,091,000	140	20	66,000	210	Average	319,000	248
10	1,037,000	230						
11	1,443,000	225	Total	16,414,000	2,100			
			Average	1,823,000	233			
Total	34,580,000	1,920						
Average	3,143,000	174						

From the above figures, which are for 26 different lines and not comparable other than by average, it will be seen that the loss of the screwed line is about ten times that of the welded line, and the rubber-coupled line is about six times as great.

Much of the loss in a welded line is due to connections at valves and attached apparatus. In constructing high pressure lines for petroleum transportation, it is possible to make pipe lines in which no leakage is measureable. Even in natural gas lines, welded joints will show no leakage if properly made and tested in the first place. Still, the gross loss, as indicated by the report, is so far below other types of joints as to be notable.

The report points out that no "standard" leakage rate can be given, each line having a characteristic leakage due to type of joint location, diameter of pipe and pressure.

The data given are a conclusive source of facts arguing for welded joints for leak-proof construction of pipe lines.

†Technical Publicity Dept., The Linde Air Products Co.

Discussion Papers 1927 Fall Meeting of American Welding Society, at Detroit, Michigan

SEPTEMBER 19-23, 1927

Pres. F. M. Farmer, A. W. S. Now, gentlemen, on behalf of the officers and the Board, I am very glad to welcome you here. We feel that the arrangement which was made this year to cooperate with the Steel Treaters will be a most advantageous one to you, not only because it affords a more interesting background for our welding exposition, but it gives us an opportunity to provide somewhat more in the way of entertainment features than would otherwise be possible. All things considered, we believe that we are going to have a most successful meeting.

The principal subject to be discussed at this meeting this morning has to do with the application of welding to aircraft construction. I am going to ask our much respected Past President, Mr. S. W. Miller, to take the chair and carry on the proceedings from this stage.

Discussion: "Welding the Aircraft Structure," by Mr. J. B. Johnson, Chief Material Branch, War Department, Air Corps, McCook Field.—S. W. Miller, presiding.

Mr. J. B. Johnson, Chief Material Branch, War Department, Air Corps, McCook Field: I appreciate this opportunity of coming before your Society and speaking of this important problem in welding, because I believe that if the brains of the welding industry are concentrated on this problem, it will help us in turning out more efficient and better designs; and of course, that is what we are all after.

This problem, from an aeronautical engineer's standpoint, involves four major requisities: These are, Performance, Production, Maintenance and Safety. I will speak briefly on how welding is applied in connection with these four requisites, and will show several slides in connection with it, in order to illustrate my points.

(The following remarks were made by Mr. Johnson in conjunction with the showing of the slides mentioned.)

In order to get your ideas fixed on the subject, I am showing this slide, which is a skeleton view of an aircraft body or fuselage. This is entirely a welded structure of circular steel tubes, with all the panel points made by welded seams, either oxy-acetylene or arc. This structure is practically standard—that is, this type of Pratt or Warren truss, with the principal members in compression under the high stresses, with occasional members in tension around the engine bearers; but the principal stresses are due to compression loads, which makes an ideal structure for welding.

Welding is not only adapted to the welding of the fuselage of

the largest bomber, but also to the very smallest size which we have flown, in which the fuselage weighed 25 pounds stripped.

Welding has the advantage that it gives a light-weight, rigid structure. Wood was used for fuselage construction during the war. In the all-steel, welded structures, which we have turned out since the war, we have been able to save about twenty-five per cent in weight.

The rigidity due to the welded panel points, also increases the life and safety of the airplane. It is my opinion that a solid, rigid structure throughout is much better than one which is pinned or riveted together. After it has been in service a while, there is always, loosening somewhere around the rivet holes. The weld, however, never yields. You can always depend upon a weld being perfectly rigid throughout its life.

In the new type of welded panel construction, all the wings are built in a Warren truss welded at the panel points. The wing beams or spars, are also made of a welded panel construction.

By the use of jigs after the welding of the fuselage is completed, every one can be lifted from the jig, and there won't be more than 1/16th eccentricity in the 20 to 35-foot length from the engine bearer to the tail surface. It requires very little straightening, and what straightening is necessary can be done generally by taking up on the tension wires in the truss.

Recently at a conference where steel structures and aluminum alloy structures were discussed, one of the points that came up for discussion was the bearing load on rivets, the bearing load on both the plate and the rivet itself; and during the discussion we found out that very few people knew much about bearing loads in rivets when applied to aircraft construction. On welds we know a great deal more, because we have done much more testing of welds than we have of rivets. Riveted construction is so old that the designer simply assumes he knows all about it, and goes ahead.

One design where rivets were used was not satisfactory until the number of rivets were increased fifty per cent, So you see, there is still something to be learned on the oldest method we know of.

In testing the finished structure of an airplane shot bags are piled on the airplane to simulate the load it gets in service. Load representing the pilot, the gas tanks and engine, the load on the tail surfaces are applied gradually, one load factor at a time, the load factor simply being a multiple of the flying load or service load, until there is an actual failure in the structure. Every new airplane is tested in that way.

Landing gears are tested under impact loading, because they are subjected to considerable impact in service. A heavy wooden frame is attached to the landing gear and it is dropped on an inclined platform. The failures are in compression in the welded tube, there is no failure of the weld, itself.

One of the difficulties we find in the use of the strong alloys of aluminum is the fact that they cannot be welded without a considerable reduction in strength, which of course weakens the joint to the point where it is not as economical as steel.

In my paper there is given a table in which the various breaking loads for these panel points is stated. We have taken several fuselages, both torch-welded and electrical-welded, cut out these panel points, and tested them in tension, in order to determine the uniformity of the welded joints obtained on a production job; and it is surprising how uniform they are.

One difficulty we have had is the non-uniformity of the steel tube, although in passing, I wish to say that the steel tube as a structural member, has been improved tremendously in the last five years. We are getting a much more uniform product than we had immediately after the war; and with our present steel tubing, which is a chrome-molybdenum analysis, practically standardized now for aircraft construction, at least on military airplanes, we are able, on account of its air-hardening properties, to develop one hundred per cent efficiency in the welded joint. In recent rules for design, which we prepared at the Engineering Division, simply as a recommendation to designers of military and naval aircraft, we have permitted the use of 95,000 pounds per square inch on simple welded joints, 95,000 pounds being the strength of a chrome-molybdenum tube after normalizing. Where we use several tubes—for instance, more than six tubes—the allowable unit stress is reduced to 60,000 pounds, because, as stated before, there is always an element of doubt just how strong the weld on top of another weld may be when they are socketed all in what is virtually a cast joint.

The next factor which I spoke of is maintenance. The maintenance engineer, of course, is vitally interested in the repairability of any structure, more so than the designing engineer. He is also interested in simplicity. Simple design is generally the best design, although it does not always show the personality of the temperament of the designer.

In connection with the repairability of the airplane structure there are a few precautions which it is advisable to bring up. In building up complicated fittings of this nature, we often use brazing in connection with welding, and it is surprising how little metallurgical knowledge there is of the effect of the two processes in combination. There is often a tendency to braze and then weld. Of course, anyone who has had any experience with welding, at least from the metallurgical side of it, knows that it is fatal to do welding over brazing; that is, as far as the strength of the weld is concerned. Yet it is often done, and we have had to issue strict orders against the practice on equipment which we are buying.

The application of welding to duralumin structures is also quite

general. We weld all the fittings that surround the tube, and in fact, on some of the latest designs, on some of the more complicated fittings, we have as much as 150 to 200 inches of welding.

So you see that although welding has been primarily applied to steel structures, it also has its use indirectly in high strength aluminum alloy structures.

Chairman S. W. Miller, Union Carbide and Carbon Research Lab.: This has been, gentlemen, one of the most interesting papers that I have ever listened to.

The meeting is now open for discussion.

Mr. L. H. Burkhart, Struthers Wells Company: Mr. Chairman, I have found that the best weld is done on the best fit. There is nothing in the paper telling us how the joints were prepared before they were welded—how the tubes were cut to make the proper sections.

Chairman S. W. Miller, Union Carbide and Carbon Research Lab.: The question is, how were the various tubes, fitted together so as to get good contact before the welding was done?

Mr. J. B. Johnson, War Department Air Corps, McCook Field: Well, there are several schemes: Generally the end of the tube is machined so that it will fit around the tube member to which it is attached, and about 1/32nd in clearance, and that is simply tacked in place.

Mr. Wm. Schenstrom, Elec. Welding Co. of America: I would like to ask Mr. Johnson what the reasons are for the failures of welds welded onto welds. I have an idea that one can weld onto welds.

Mr. J. B. Johnson, War Department, Air Corps, McCook Field: Well, I don't know as I can tell you the reason. All I can tell you is our experience. We have found they are weak, much weaker than the original weld.

Mr. W. Schenstrom, Electric Welding Co. of America: Has that anything to do with the character of the steel?

Mr. J. B. Johnson, War Department, Air Corps, McCook Field: No. That is, it is true of whether we are using a low carbon steel or whether we are using alloy steel. Of course, we use the same welding there for either.

Mr. W. Schenstrom, Electric Welding Co. of America: But the steel that you weld on is not the low carbon steel, is it?

Mr. J. B. Johnson, War Dept., Air Corps, McCook Filed: No. It is about .30 carbon average, with a molybdenum and chromium content, Chromium about 1 per cent, molybdenum about .25.

Mr. Knerr, Philadelphia: I have had a certain personal interest in aircraft, having had a position somewhat similar to that of Mr. Johnson with the Navy Department, and I want to compliment Mr. Johnson on his very, very valuable and interesting paper.

I am heartily in accord with practically everything he said. There are a few points that I would like to raise, with your permission.

I feel very strongly, as the rest of you no doubt do, that welding

has come to stay in aircraft, and I do not want to appear as being a crabbed critic in any way; but I do want to raise these points, because I think that if we recognize them we can deal with them more intelligently.

Mr. Johnson has raised a very pertinent point in the first page of his paper, when he mentions the distortion of welding having probably arisen due to the fact that in small plants, skilled welders were not available. Now, you have the whole thing there in a nutshell. I think we ought to keep that very much in mind. In case of emergency, war emergency, we may have many new welders suddenly broken in, and possibly their work won't be as skillful as that of more experienced welders. What are we going to do about it?

Another point is the question of maintenance of repair in the field.

There still seems to be, as we all know, a very great need for some way of testing a weld without breaking it. The proof load is good, but perhaps not enough, because failures sometimes occur by breaks from a small crack or fissure, which will not fail under a proof load but which will fail under a much lower load, under vibration or repeated stress.

He mentions, however, that if aluminum alloys could be welded without serious loss of strength, the problem of light metal wing structures would be simplified. I believe there is also another point there: The successful welding of aluminum alloys depends on the use of suitable fluxes. The only fluxes we have are very corrosive, and must be removed absolutely in order to prevent the serious deterioration of the weld at the time. It is sometimes quite a problem to find out how to get the welding flux out of the gusset or tubular welded structure.

In Table 1, Mr. Johnson gives some values for tensile strength on welded specimens, and mentions the average values. Those values are fine, but it is the minimum values which count in the structure, and we would like to know, perhaps, what the minimum values have been.

On the next page, page 106 of his paper, he mentions the design load of 80,000 pounds for the weld—and says that with a fish-tail weld or some further gusset plates, that can be increased. I would like to ask Mr. Johnson on what basis he figures the area for calculating the stresses—whether he figures the full area of fish and gusset, or the contracted area of the tube.

Another point with welding that we have found a serious one with the Navy, where we are exposed to salt water and corrosion a good deal, is the fact that the included surfaces in welding are very hard to protect; that is, between the joined surfaces, it is very hard to protect those against corrosion. Moisture gets in there, and sometimes we have a serious corrosion internally, where the outside of the fitting seems to be entirely sound.

The use of dip brazing after welding has given very good results, because if that is done right it gives you a very sound hermetically sealed joint, and a very strong one. Of course, you must not reverse the process by welding again after brazing. By the way, that again bears out the fact that welders are not always as careful as we expect them to be. I thought all welders knew better than to weld after brazing, but apparently they do not.

One other point at this time: Mr. Johnson has discussed the use of round tubing in welds. It is a fact that a square tube of equal diameter across flats is somewhat stronger, stiffer, as a column, than a round tube of the same weight. That gives you a somewhat more efficient structure and a lighter structure; also, it has been found that the square tube is easier to join.

Chairman S. W. Miller, Union Carbide & Carbon Res. Labs.: Mr. Johnson, can you answer that question which was asked about the method of computing stresses?

Mr. J. B. Johnson, War Dept., Air Corps, McCook Field: Yes. We compute stresses on the projected area.

Chairman S. W. Miller, Union Carbide & Carbon Res. Labs.: Is there anything else that you would like to say in reply to your Navy colleague?

Mr. J. B. Johnson, War Dept., Air Corps, McCook Field: No. I think the points that Mr. Knerr brought up are very good. We have not used any square tubing for welded structures.

Mr. R. G. Mason, Santa Fe R. R., Chicago: Mr. Chairman. There was one question brought up relative to which I would like to have a little more information. You spoke of the rivets and mentioned the wear, and therefore that welding would be better than riveting. What causes the rivets to wear? Is there a vibration?

Mr. J. B. Johnson, War Dept., Air Corps, McCook Field: Yes. There is a vibration. It is not a severe vibration, but it is a tremor which comes from the engine.

Mr. R. G. Mason, Santa Fe R. R.: Do you anneal any of the welding? After the entire fuselage piece is welded do you anneal the entire fuselage, or do you just locally anneal, or do you do any?

Mr. J. B. Johnson, War Dept., Air Corps, McCook Field: No. We have tried annealing the fuselage structure, but it is a very difficut operation in the first place, because you have to surround each point by a refractory of some kind and apply heat; and another thing, I question whether it is advisable to do it, because you may be using a cold worked tube. There is a certain amount of strength due to the cold working, especially with the carbon steel, and if you destroy that effect by heating the tube beyond the weld you weaken the tube that much, without any added advantage.

Mr. R. G. Mason, Santa Fe R. R.: I see in your paper that you have used chrome steel, I believe, heat-treated.

Mr. J. B. Johnson, War Dept., Air Corps, McCook Field: We have used heat-treated structures, and are using them more and more.

I mentioned that in the paper. I believe I forgot to bring it out in the lecture. We are using two types of heat-treated structures: We are using one type in which we weld the alloy steel and heat-treat after welding. That has been quite satisfactory for fittings —even quite complicated fittings. Then we use the other type, where we heat-treat before welding, and weld the heat-treated parts.

Of course, then there is close to the seam a softened area, but generally it has a larger area than out in the lug section; and we have found that that is satisfactory. Now, metallurgically that sounds bad, but the aircraft engineer is constantly working on the border-line in connection with his design. He is constantly getting beyond what is considered good practice in other engineering fields, and I believe he is doing it successfully.

Mr. R. G. Mason, Santa Fe R. R.: How would you go about to heat-treat after you make a weld?

Mr. J. B. Johnson, War Dept., Air Corps, McCook Field: We quench in oil and draw. In that case we have to be careful, on a complicated fitting.

Mr. R. G. Mason, Santa Fe R. R.; In the lap-welding or over-welding would it be any advantage to anneal first and then make a second weld?

Mr. J. B. Johnson, War Dept., Air Corps: I rather doubt it. I think there is bound to be some slag on the surface of the original weld which causes the trouble.

Mr. R. G. Mason, Santa Fe R. R.; Would you sand-blast or anything like that? Of course, your first weld is cast, and that might have something to do with it, too.

Mr. J. B. Johnson, War Dept., Air Corps: Yes, it might help to sand-blast it. We have not studied that phase.

Mr. James W. Owens, Director of Welding, Newport News Shipbuilding and Dry Dock Co., Newport News, Va.: Mr. Johnson stated that welded joints of a 100 per cent ultimate strength could be obtained in steel tubing; however, he did not state whether those joints were subsequently heat-treated.

My reason for calling attention to this is that about two years ago I conducted a research for the Bureau of Aeronautics on the tensile strengths of metal arc and gas welded airplane joints in mild, nickel and chrome molybdenum steel tubing, using mild steel filler metal. The investigation showed that the thermal effect of welding reduced the efficiency of the tubes in tension about 20 per cent. In view of this I recommended that this amount be deducted from the ultimate strength of the material in design.

On completion of my investigation, I noted in the Journal of the American Society of Naval Architects of November, 1925, that the Fokker Works at Amsterdam also allows, as a result of tests, a 20 per cent reduction for the strength of gas welded mild steel tubing.

It might be possible to utilize steel tubing with welded joints for the construction of larger dirigibles than we have at present and which are proposed. The joints of a semi-dirigible constructed in Europe, using steel tubing, were made by flattening the end of the abutting member to conform to the contour of the tube, lashing it with wire and then soldering it. It seems to me that a welded joint is to be preferred.

Mr. Slack remarked to me a few minutes ago that it would be well to call attention to the possibility of other industries engaged in welding advantageously utilizing joints and methods now used in aircraft construction. The suggestion is very pertinent and should be given attention. One of the principal joints used in welded aircraft construction is the use of a gusset plate inserted in the slit tube and the end of the member to be attached to the tube. This form of joint can hardly be improved upon for strength and because of its general construction gives confidence to those who would otherwise reject the welded joint, and I have advantageously used it in awning stanchions, mast and boom fittings for ships. In mast and boom fittings considerable money and weight can be saved by its use as it replaces bands which entirely circle the mast or boom.

Mr. J. B. Johnson, War Dept., Air Corps, McCook Field: I want to answer one question brought up by Mr. Owens, relative to why we can use a full strength of 100 per cent efficiency. We do that with chrome molybdenum steel, which is an air-hardening steel. It has been our experience that this steel hardens from the welding heat, air-hardens to about 100,000 pounds per square inch. We have also found that with the plain carbon steel of medium carbon content we get slight air-hardening effect. At least, we do not lose the strength of the original tube. The type of tube used by Fokker in his original work was a low carbon steel, containing about 15 points carbon. The strength of the tubing was raised by cold work on the draw handle. A great portion of this strength is lost by heating. On that basis we only allow an ultimate stress of 40,000 pounds in a 0.15 carbon steel tube which has an original strength of 55,000 pounds, of which 15,000 is due to cold work.

Mr. M. L. Eckman, Ford Motor Co., Detroit: I would like to ask Mr. Johnson if he has had any experience, or if he knows of any other company that is working any on the resistance type of welding of the tubing? Of course, I know it would be quite hard to fabricate a fuselage resistance-welded all the way through; but I would like to ask him if he knows of any work being done on Chrome-molybdenum steel along that line?

Mr. J. B. Johnson, War Dept., Air Corps: No. My only experience with the resistance welding has been the welding of hollow valves. We tried to weld the heads on some hollow valves. In that particular case we were not successful. I don't know whether it was the process or the steel. Of course, it was a steel

with a high alloy content. We could not get a sound weld. All the welds were porous.

Mr. A. B. Kinzel, Union Carbide & Carbon Research Laboratories: I should like to point out that the practice of welding materials which have been previously heat-treated is not in some cases as illogical as it sounds. Stress analysis shows that in the case of a strut or other member subject to bending moments, the maximum fiber stress due to these bending moments occurs at the center of the bar and the fiber stress at the ends is quite low. Thus, in welding a heat-treated bar we are reducing the ultimate strength only at the point where the piece is not called upon to withstand such high fiber stress and in the center of the bar, the heat-treated condition remains unaffected and takes care of the high stresses.

One other point. Mr. Knerr's statement that the square tubing is better for the job than round tubing. We know that our bending movements have to be taken into consideration. The moment of inertia determines the performance of the section under discussion, and the round section has undoubtedly the greatest moment of inertia.

I don't want to challenge Mr. Knerr's statement, but I do want to ask him what other considerations there are which caused the designers, aeronautic designers, to choose square tubing instead of round tubing.

Mr. Knerr: I don't think that Mr. Kinzel got the qualifications: I said square tubing and round tubing of the same diameter, taking the diameter of the square tube across flats, and the same weight per unit of length, I think you will find that the square tube has a moment of inertia nearly a third greater than the round tubing under those conditions.

Mr. A. B. Kinzel, Union Carbide Labs.: With the same weight?

Mr. Knerr: The same weight and the same diameter across flats; your square tube is much thinner than your round tube and has a greater moment of inertia.

Flying Officer Luke, Inspector of the Royal Canadian Air Force: I think the most astonishing statement I have heard is the one in connection with chrome-molybdenum steel, claiming 100 per cent strength at the welded joint; because that is one thing, the strength of the welded joint, that we have had to contend with for some time, and we have not allowed more than 80 per cent. I am going to see my brother afterwards just to see where he gets his figures from, because if that is the case, that chrome-molybdenum steel is going to give us 100 per cent at the joint, it certainly is going to affect welded fuselage construction.

The mention was made of protecting the inside of the tube by using oil. Now, I have found, especially in repairs on the field, that where the inside of the tube has been treated with oil it bothers the welder, not only from the point of view of smoke, but there is a scale of some kind which gets into the weld, and if

the repair weld is done over an old weld I certainly have lots of trouble. I tried to get some method of welding, and in testing a weld under those circumstances, I found that an automatic punch gave me a very good test, and by keeping a fairly heavy pressure on the spring right at the point near the weld I could frequently drive the point right through that section. It was absolutely brittle.

When all is said and done, if you have a trapped-in tube there is at no time more than one-seventh oxygen in the air. Take it for granted that all of that oxygen conbines with the inside of the tube and forms an oxide, what is the depth of that coat of oxide and does it affect the strength of that tube to any extent? My suggestion is that it is better not to oil treat the inside of a tube, but to trap both ends and just leave them trapped. You have a hermetically sealed joint, and I wonder if one could have anything much better than that.

I would like to hear opinions on that.

Square tubing: I have just recently examined a new long-distance photographic machine, the preparation of which is now going on, in which square tubing has been used on the front section. It is built up in three sections: Tail section, center section out of round tubing, and the front section of square tubing. I have found that the fitter has a much easier job with the square tubing. The welder likes it better, too, because he finds that he has not got to use such a very small torch. He can standardize more on his tips and go straight ahead with one size.

The only difficulty is in bending. For instance, in this particular fore part of the fuselage construction, we have several circular members. The two cockpits, for instance, and then the whole of the front is bowed out so as to allow the photographer all kinds of room in turning around. Now, we did have some difficulty in bending that tubing. We tried filling with sand, and to imitate a method which is in vogue by one of the steel bed companies, by filling the tube with lengths of very thin spring steel. No doubt it would be a very good method in production, but for an experimental machine it naturally would double the price.

Does our friend, Mr. Johnson, approve or disapprove of completing a joint where several tubes meet at the point—for instance, in the illustration we had on the sheet there were ten tubes or more meet at one point—does he approve of completing the whole of the job at once, or doing a part of it only and coming back to the job when probably the welder has been to some other part of the machine? I have often wondered whether it materially affects the strength by doing a part only of a complicated joint and then coming back and finishing it afterwards, when it has somewhat cooled off; though in some of the construction it is a much easier job to do the whole thing at one time.

Mr. J. B. Johnson, War Dept., Air Corps: I have been very much interested in the statements that have been made.

Regarding the use of an ultimate stress of 95,000 pounds in chrome-molybdenum tubing, I can simply reiterate what I stated before, that it is an air-hardening steel, and it has been our experience that we can develop 95,000 pounds in the steel after welding. We have several designs in the simpler joints—that is, where not more than three or four tubes come into a joint—where we are allowing the designer to use 95,000 pounds, and these airplanes have been in service, some of them, for two or three years without any failures of the welded joints.

With regard to the protection of tubing by oil: That has been the subject of considerable controversy, because it is an added expense, and naturally the contractor does not like it; but we have felt that it is necessary on account of the varied conditions under which our airplanes may fly. It is true that if you hermetically seal the tube you probably do not have enough oxygen in there to seriously corrode it; but our airplanes may go to Panama or the Philippine Islands, where they have a long wet season, or they may fly along the sea-coast. In fact, about six months ago we had one come back from one of our flying fields near the sea-coast which was very badly corroded on the outside. There was very little corrosion on the inside. That job had been protected with oil, but the sea water was still on the inside of the tubes and had to be poured out after the fuselage came to Dayton. We tested some of those tubes. The strength was not seriously affected by the corrosion, but the ductility was quite seriously affected. Where the original ductility was probably on the average 20 per cent, it had dropped to about 8 to 10 per cent. And probably the fatigue strength, the strength under vibration, would be seriously affected. Therefore, we consider the corrosion problem very important, and believe some potection is essential.

There is another point: We use linseed oil rather than mineral oils inside of the fuselage. One reason for that is that no weld is absolutely tight. You all know that. That is, the ordinary structural weld; you may be able to make the weld in a pressure vessel tight, but the ordinary weld in an airplane fuselage is not absolutely tight, and some oil will seep through that joint. When we use mineral oil we have trouble with the coating, such as paint and enamel peeling around the weld. When we use linseed oil we do not experience that difficulty. We have experienced no weakness due to the linseed oil getting into the weld.

We have made some experiments, checking up possible carelessness in the field due to failure to remove the outside protective coating. We coat the outside of the structure with an iron oxide primer coat, followed by a coat of spar varnish containing aluminum powder. We have found that coating to be as good as any we have tried. When it is not removed, the weld becomes contaminated and is not up to full strength.

Mr. A. G. Bissell, Westinghouse Elec. & Mfg. Co.: There has

been something said about the effect of poor welding. I thought you might be interested to know the system used by one of the manufacturers of aircraft who is using arc welding in the fuselage construction.

At first, when they started to weld and they got a production job, they put on a bunch of men, broke them in and started to weld, and then when things slackened off they laid the men off. When they got another order they put a bunch of men on again, and so on; and the result was that they had more or less trouble with their men and had trouble with their welds.

.Now, that plant is working along pretty well on chrome-molybdenum steel. Each man has a certain number of joints, certain types of joints that he welds, and that is all he welds. Another man does another type. Each man is a specialist; and when work slacks down those fellows sit there and read or study or practice until work picks up again. In that way they are keeping their experienced men, and they tell me they are saving more by doing that than they were by trying to lay their men off when the work was slack.

Mr. A. D. Camp, U. S. Aluminum Co., Buffalo: Mr. Johnson spoke of the difficulty of welding strong aluminum alloys, and I would agree that this has in the past been found to be a rather troublesome job. Within the last year or so, however, we have made considerable progress in obtaining sound welds in complicated structures composed of strong aluminum alloys by the use of a welding wire consisting of about 5 per cent silicon with the balance aluminum. Our explanation of this beneficial effect is that the deposited 5 per cent silicon alloy, having a considerable lower solidification contraction and a lower melting point, remains in a partially molten or ductile condition sufficiently long after the base aluminum metal has frozen to fill in the voids like a gate in a casting, and thereby relieves the heavy strains normally set up in a welded joint.

Tensile strength tests of butt welded strong aluminum alloy specimens indicate that we obtain from 70 to 80 per cent of the ultimate strength of the metal in the welded joint. Since the welded area of these heat treatable alloys apparently gets an air quench upon the removal of the welding torch, the weakest spot in the joint is usually at a point from one-half to three-quarters of an inch back of the weld where the heating effect has only been sufficient to partially anneal the metal. We have not yet made fatigue tests of these welded joints, but tensile strength tests indicate, as I said before, from 70 to 80 per cent of the ultimate strength of the metal.

The speaker from the Canadian Air Force and others have mentioned the difficulty experienced in bending without buckling square metallic tubing, which has retarded its use in aircraft construction. I would like to call your attention to bending machines, now

largely used in the manufacture of metal beds, which bend successfully square tubing of a wide variety of sizes. The Buffalo Fabricating Division of the U. S. Aluminum Co. is now installing a machine for bending square strong alloy aluminum tubing of moderate cross section and wall thickness over a three-inch radius without the slightest buckling effect in the manufacture of chair backs. The machine is very simple and rapid in its action. Outside of its bending mechanism it consists of two mandrels which are forced into either end of the straight tubing. At the end of each mandrel are a couple of links which exactly fit the inside of the tube. When the outside ends of the mandrel are drawn together to form the bends, the mandrels are slowly withdrawn in such a way that the links are always at the points of curvature. The tube is, therefore, supported on all four sides, which absolutely prevents any buckling. We are making bends in aluminum tubing as small as three inches radius, and it is quite likely that bends of even smaller compass can be made. The same is true for steel tubing.

Chairman S. W. Miller, Union Carbide Laboratories: I would like to point out in a general way the essence, as I see it, of these two papers: It is the care that has been taken in the control of the procedure all the way through. There has been nothing haphazard in any part of the whole work. The material has been properly selected, the welders have been tested, the design has been correct, and the supervision has been ample. Those in charge are thoroughly alive to the need of correctness in all the various links of the chain, and I just want to add one word: That in no case in which welding has been done in that way has there been any failure.

Discussion paper, **"The Bend Test as Applied to Welded Coupons,"** by Mr. W. B. Miller, of the Union Carbide & Carbon Research Laboratories.

Chairman S. W. Miller, Union Carbide Laboratories: One of the first things that the American Welding Society did was to devise methods of testing which were contained in their Bulletin No. 1. The arrangement for bend testing that was shown is in that bulletin. Now, it seems that it is necessary for us to reconsider our viewpoint, and it may be well for the Society to consider changing its recommendations in that respect.

If there is anybody that would like to ask any questions or make any remarks in connection with this paper, I would be glad to hear them.

Mr. F. N. Speller, National Tube Co.: May I ask what Mr. Miller recommends, and the real significance of the bend test in testing welds—there is some difference of opinion as to the value of a bend test in ordinary material—what is the practical value of the test?

Mr. W. B. Miller, Union Carbide & Carbon Research Labs.: I

think that question came up in connection with Mr. Kinzel's paper yesterday. They asked what value it (the bend test) had over the tensile test as a measure of ductility. Well, it probably has none. We thought it would be applicable to any kind of plate weld in the field. By taking a small piece from a weld and making a bend test, you can get an idea of the quality of the weld. As to gage length, we took an inch, which just about covers the width of the weld in ⅜-in. plate. With thicker materials it would probably be best to increase the gage length.

Mr. F. N. Speller, National Tube Co.: You would get a different percentage.

Mr. W. B. Miller, Union Carbide & Carbon Res. Labs.: Yes, that it true. However, one inch seems to about cover the average width of weld in ¼-in. to ⅜-in. plate. I cannot give any definite reason for taking any one gage length, except that one which takes in the width of the weld metal would seem most logical, since we are primarily interested in the quality of the weld. Maybe Mr. Kinzel can help me out on that?

Mr. A. B. Kinzel, Union Carbide Laboratories: The gage length chosen must be such that all the metal included in the gage length has about the same fiber stress. Now, if you take a piece with a sharp bend in it, so that the actual fibers that are stressed only take about a quarter-inch, and then take about a one-inch gage length, you are not doing a good job; in ordinary welding the conditions are such that by taking the gage length about one inch you do cover the section of practically uniform fiber elongation. That was done in the specimen which Mr. Miller put on his slips, marking off in one-eighth inch gage lengths. We did that in order to find out specifically how far away from the center of the bend we still got uniform fiber elongation.

The gage length chosen depends on the kind of a bend, and the point to which you go with your test. If you took a piece of ordinary sheet steel one-sixteenth of an inch thick and applied an inch gage length on it, you would be all wrong. That is obvious.

The other method which Mr. Miller mentioned, namely, as being discussed in my paper before the Steel Treaters Society, taking the curvature at the point of maximum fiber elongation, eliminates the matter of gage length entirely. But for normal practice, where you have certain standard conditions, you might use that to determine what gage length you should use, and that is what Mr. Miller has done in determining this gage length for the welding tests he is performing.

Chairman Miller: Is there any further discussion?

Mr. A. B. Kinzel, Union Carbide Laboratories: I have been asked recently to head a committee of the American Society of Testing Materials to look into the bend test. In view of Mr. Miller's remarks just preceding this discussion, I think it would be a good idea if we could get together, the American Welding Society and

the American Society of Testing Materials, and work out something that is universally satisfactory.

Mr. Knerr: The question has been raised several times as to the value of the bend test as against the tensile test as a measure of ductility. I cannot say very much about bend testing of welds, but I can say that the bend test will reveal characteristics in steel which you will not find with the tensile test, no matter how carefully you make it. That has been the case in the inspection of sheet steel for aircraft purposes, where the steel had to stand severe bending and also had to stand severe stress and fatigue.

We bought under specifications calling for tensile strength, yield point, and a minimum per cent of elongation, and we also put in a requirement for a bend test. The bend test was applied in the annealed state, whereas the tensile test was applied to the material in the heat-treated stage; but, nevertheless, a bend test is a remarkably good thing if it is properly performed, for showing up flaws or defects in steel which may come from the ingot stage.

We had a certain case, for instance: Some sheet showed a greater elongation in transverse tensile specimens than it did in longitudinal, which is contrary to common sense, and it was because that steel was so defective that it expanded like expanded metal wire, more or less due to the numerous small fissures. Now, under a bend test that metal would simply split in half.

Furthermore, our experience with the bend test has been that it is a very peculiar test; I mean, you have to standardize very carefully on the way you make it, because you make a bend test in different ways and you get different results. You also have to take into consideration the thickness of the material you are bending, because the same bend for a different thickness gives you a very different answer.

Mr. A. D. Camp, U. S. Aluminum Co., Buffalo: I might call attention to the fact that it is difficult to get much useful information regarding the ductility of a welded joint from the elongation measured during a tensile strength test on account of the non-uniformity of the material in the test specimen. Adjacent to the material of cast structure deposited in the center of the weld is a partially annealed section gradually merging into the original metal unaffected by the heat applied during the welding operation. Since the partially annealed section contains the weakest spot in the test specimen, the fracture in normal welds always occurs at that point, and since the necking is highly localized in the small annealed region, the calculated elongation percentage is very much smaller than it would be if the whole specimen were of a uniform quality of material. A tensile strength test of a welded specimen of 51SW aluminum alloy which is in the heat treated and quenched condition will show from 5.0 to 7.5 per cent elongation, while an unwelded piece of 51SW material will have from 15 to 23 per cent elongation in 2 inches.

Chairman Miller: I might mention one thing in general and that is that in any weld, or in any welded piece, I think it can be said that it is universally true that the yield point of the weld metal is higher than that of the base metal. That supplements what Mr. Camp has said, but I think makes it a little bit more clear.

The reason for the elongation occurring at one spot is, of course, the same as it is in any test piece: It begins at the point that has the least resistance, and as soon as any necking down occurs, the unit stress at the neck becomes greater and the piece eventually breaks at that point.

One advantage of the proposed bending test is that you can get the ductility or the elongation in any particular part of the test piece that you want. If you want to measure it on a quarter of an inch width of the weld, you can do so. In a tensile strength specimen that is not nearly so easy.

Mr. A. B. Kinzel, Union Carbide Laboratories: Mr. Knerr mentioned that the bending test has been a very finicky test to carry out. He is quite right; that has been the case. However, with the present method of measuring the results it is not near as finicky as it used to be, and it may be carried out in almost any machine in any way, without any undue precaution, and then the elongation measured, and you get consistent results.

There is one thing you do have to look out for. When applying the bending movement you must not at the same time apply tension, because then the tension applied to the outside fibers is not a function of the radius or of the bending movements, but is a complex function; so you want to get away from that. It doesn't make much difference if you do it in the vise or in any other way; it is the final elongation that counts. So the finicky part of the test has been pretty well overcome.

Mr. F. N. Speller, National Tube Company: The method of measuring and comparing bending tests is very interesting and may have a certain field of application where pulling tests cannot be made, as in the case of fusion welds. It appears that the elongation measured is that of the most strained fiber and is the maximum elongation rather than the average over a certain gage length, as indicated in the elongation of a tensile test piece. It would seem to be desirable to have a uniform distance between the gage points just as in the case of a tensile test piece.

We all know the bending test is generally used as a rough and ready measure of the ductility of the metal, and serves this purpose very well, but as now made does not afford a comparison between materials of different sections.

The work done by the authors of this paper should assist materially in putting this test on a more substantial and more uniform basis.

I just mention that because it is not going to be quite so simple to get this in figures as you might think.

Mr. A. B. Kinzel, Union Carbide Laboratories: I think Mr. Speller will find it is going to be quite simple when he tries it. As far as the different gage lengths go, that is the very point we are getting away from. That is, it doesn't make any difference what gage length you are testing: If you get the elongation of the fiber an infinitesimal section across, the initial point of fracture, that is all you want. Now, if you get that by taking that infinitesimal section or by taking a much longer gage length, which is more convenient to measure, that is a matter to be decided; but the method I have shown, of taking the radius, gives you the elongation right at that point.

Chairman S. W. Miller, Union Carbide Laboratories: I think that Mr. Speller's suggestion is most admirable. I don't think the Welding Society or the Steel Treaters, or both of them together, would be wise to attempt to establish standards for this test. It is of far wider scope and of far wider interest than to those two societies alone. I feel that before this thing is properly carried out, the Society for Testing Materials, and probably a good many of the other people that are interested in the thing, will be called into consultation.

TUESDAY AFTERNOON SESSION

The meeting was called to order by Mr. F. M. Farmer, President, at 2.15 p. m.

Mr. F. M. Farmer, American Welding Society: The second session will please come to order. We have a very interesting program this afternoon. Certain features of it, at least, ought to appeal to some of our more high brow members. There certainly is ample material for discussion.

Without any further comment on my part, I will introduce the presiding officer of this afternoon, Professor H. L. Whittemore, Mechanical Engineer, Bureau of Standards.

Discussion paper, **"Heat Treatment by the Oxy-Acetylene Flame,"** by E. Thum, Associate Editor, *Iron Age.*

Mr. H. L. Whittemore, Bureau of Standards: One of the beauties of Mr. Thum's paper is that you can do the things he has been describing with the apparatus at hand. I wish I had known about these things when I used to break off taps in the shop, and never got them out, so far as I can remember. I am going to bring this information to the attention of the mechanicians in the shop at the Bureau, especially those who work with us. One of the troubles that we have had is that if we had a cold chisel or a piece of steel that we want hardened, we go over to the metallurgical division, and they insist on having a chemical analysis before they will heat treat it. They will argue with you. I have never got them to treat anything without a chemical analysis; so, of course, we have been held up. We are going to do it Mr. Thum's way now.

There ought to be some discussion on this. A good many of

you must know of applications of these methods which perhaps Mr. Thum has not heard of.

Discussion, **"Report of San Francisco Section's Investigation on 'Study of Welds Subjected to High Temperatures,'"**

Mr. W. Spraragen (Editor, JOURNAL): This investigation was carried out by a local section of the Society, the San Francisco section, working in cooperation with National Headquarters. It was felt that the group in San Francisco had the means and the personnel to do some very creditable research work. Mr. S. W. Miller, then chairman of the Gas Welding Committee, happened to be in that section, and got them interested in a study of welds subjected to elevated temperature.

This is a new problem, and the committee had to grope its way, so to speak, developing equipment, test specimens, etc., to do this work. Of course, they had the advantage of the best advice we could get, including the Bureau of Standards, and other investigators.

I am very sorry that the chairman of this sub-committee cannot be present, but San Francisco is a long distance away. He asked me to present this report. I think it is short enough to read, and then I would like to show a few slides.

Mr. H. L. Whittemore, Bureau of Standards: You have all heard this excellent paper. I think it illustrates what can be done if you get people interested in obtaining information which is of value to the users of a process.

The paper is open for discussion. Some of you must have had experience with welds at high temperature.

Mr. S. W. Miller, Union Carbide Labs.: I think it would be a most appropriate thing, Mr. Chairman, if we were to extend to the San Francisco section a very hearty vote of thanks for the work that the San Francisco section has done, and wish them God-speed in the rest of the work. (The motion was duly seconded.)

Mr. H. L. Whittemore, Bureau of Standards: A motion is made and seconded that a hearty vote of thanks be tendered to the California section for this very valuable paper. (Motion adopted.)

Mr. J. J. Crowe, Air Reduction Sales Company: I think it would be interesting if Mr. Miller or some one would tell us more about the reason for carrying out this investigation.

We all know in oil refineries, and in places of that kind where they are using welding, they go up to temperatures comparable with those investigated. As I understand it, some of the new power house installations go up to one thousand pounds pressure, and something like a thousand pounds super heat. Information of this kind would be very interesting in designing pipe line installations for power houses, and for other purposes.

Mr. S. W. Miller, Union Carbide Laboratories: I do not believe, Mr. Chairman, that there was any specific object in view—not so far as I know. The whole subject of the strength of metals at

high temperature is one which has been agitating the engineering profession in all its branches for several years. Mr. Crowe has mentioned a few of the specific questions that have been raised, such as distortions in pipe lines of ordinary cast iron valves. There is a suspicion in the minds of people that welding is a mere pasting operation; that you might as well use a piece of chewing gum, or molasses, or something similar; that it is not a true union; that it is only a soldered joint; and a lot of other things like that. It puts questions of the strength of welding at high temperature on exactly the same par as the strength of other metals at high temperature. A lot of work has been done on it, and I might say, considering what Mr. Crowe said, that during the last two or three years, particularly, steam pressures have increased so rapidly, and superheats have been raised to such a degree, that all metals are more or less under suspicion—under trial, if you will—in these high pressure, or high super heat installations.

As a welding society, we are naturally interested in welding pipe line. We believe that the weld is by far the best method of joining pipes. It is the cheapest, most reliable, most permanent, and in every other way the most satisfactory, but these suspicions and lack of knowledge of facts in connection with welds made it appear to the Board of Directors and the Executive Committee of the Society that it would be wise to find out something, if it were possible to do so, about the whole subject. And at that time it was thought that it might be possible to interest some of our sections in specific problems of this kind. The Detroit section, for instance, might very well select some research problem, the solution of which would be of very great benefit to the welding industry. However, the San Francisco was picked as the one for the first trial, and I think that they have done a mighty good job. So that one of the lessons we might draw from this report is that the sections of the American Welding Society can be of tremendous benefit to the welding industry, if they will pick out problems that are suitable to their membership—because problems are different in different localities—and carry out what is a real research on that particular job.

When this thing was started nobody knew where it was going to end. Nobody knows yet what is going to be the result of it. But if the fundamentals are established, and the apparatus available, there is no reason why the San Francisco section should not carry the thing to such a conclusion as would be worthy of the American Welding Society, and worthy of the name of real research. I suggest to the other sections that they gird up their loins and proceed along the same path as the San Francisco section has.

Mr. W. C. Sprau, Barnes Wire Fence Company: I want to say a word in behalf of the Detroit Section. A group of welding engineers, structural engineers and architects assembled here in Detroit

a few months ago for the purpose of introducing welding in fabrication of structural steel buildings. Emphasis were placed first on minor connections, such as members introduced for wind bracing. A number of sample test pieces were prepared and tested, the results of which will appear in a paper by Mr. Matte of the Albert Kahn Company, architects of Detroit. The material for making tests was furnished by the structural shops, the welding carried on by the welding engineers and plans and designs for various tests prepared by the architects all gratis.

We have attempted a big problem, probably larger than we have means to complete, but will go ahead and see what results can be obtained. The members of the building department are cooperating in these studies and the feeling is that we have met with some success. Thus far the building department have agreed to certain construction with welding. We are carrying on with the hope of getting further concessions.

The purpose of these remarks is to indicate that we are trying to do our part of the research work that might be expected of local sections.

Mr. James W. Owens, Newport News Shipbuilding and Dry Dock Co.: An investigation made by me on the effect of heat treatment of metal arc welds also disclosed that weld metal is extremely brittle at or near 1000 deg. F., and that such welds cannot with safety be subjected to stresses when at or near this temperature until a method of preventing nitronization and oxidation during welding is developed. The tests conducted by the San Francisco section, therefore, verify this conclusion. A peculiar phenomenon observed was that although the metal was extremely brittle, it was practically as soft as lead. A report of my investigation will be found in the May, 1921, issue of the *Railway Electrical Engineer*, and the April, 1921, issue of the *Welding Engineer*.

It has been pointed out that as a result of the numerous welding investigations that are being carried on to determine the strength of welds, we are beginning to know more about structural welds than is known about the metals welded, thus making it possible to design better welded joints than riveted joints. If similar investigations are conducted upon base metals at high temperatures, it is probable that similar conditions will be found.

Mr. W. Spraragen: I would like to sound a word of caution in this matter of research work. The San Francisco section went about their investigations as scientifically as any group could be expected to. They first made a critical review of all the existing information, including tests made of welds and parent metal. Secondly, they set up some very rigid procedure specifications to be followed in making up the specimens. That can easily be seen by the fact that they tested their welders before they were permitted to weld specimens. The results they obtained as to the

ultimate strength of the samples tested when they were cold (welds made with low carbon welding wire, for instance, runs from 54,600 to 61,000 per square inch) shows that they did some pretty good work there. These samples were machined flush with the parent metal, and even the small holes for the potentiometer could not be taken care of. That is, the welds were penalized because of those small holes. Carrying out a series of research tests without some very careful preliminaries will give you a lot of data that do not amount to anything. There will be more variables than there will be test results.

Mr. H. L. Whittemore, Bureau of Standards: I believe that is a very wise precaution. The fact that this paper from San Francisco section gives errors and the depth of the effect of torch cuts, and things of that kind inspires confidence in the results.

Discussion paper, **"A Metallurgical Study of Welds," by G. R. Brophy, Research Laboratory, General Electric Company.**

Mr. R. A. Bull, Electric Steel Founder's Research Group: Mr. Chairman, I had the opportunity to read Mr. Brophy's interesting paper a couple of days ago, so I took the time before coming here to write a brief discussion on one phase of the paper.

The author's preliminary statements are of particular interest in that they quote the tensile properties of a bar machined entirely from deposited metal, and a bar machined from the bead of two ¾ in. plates jointed by welding with the same wire as used in the first instance mentioned.

In the case first cited, the operator is stated to have obtained a tensile strength of 61,300 lb., a yield point of 44,100 lb., an elongation in 2 inches of 24 per cent, and a reduction of area of 35 per cent.

When the weld of the ¾ in. plates was made, using the same quality of wire, the results obtained were said to be as follows: tensile strength, 49,000 lb.; yield point, 35,600 lb.; elongation, 11 per cent, and reduction of area, 15 per cent.

Mr. Brophy, after giving these results, states that "this indicates that a good deposited metal is being contaminated by a poor quality of plate stock." Nothing in the paper following this statement appears for the purpose of explaining the extraordinarily good ductility of the welded bar whose properties include a reduction of area of 35 per cent; nor to explain the manner in which the author reached the conclusion as the result of these two tests that the bar showing 15 per cent reduction of area was contaminated by poor quality of plate stock.

In the absence of any explanation regarding special and unusual equipment or methods for producing the weld having 35 per cent reduction of area, the reader is justified in feeling it to be Mr. Brophy's opinion that the weld referred to has properties characteristic of current good commercial practice. I think, in view of

the present state of the art of welding, that it would be unfortunate for several reasons, including the desirable further application of that art, if engineers who have to do with the fabrication of steel structures would be induced generally to believe that good commercial welding practice, as now employed, produces tensile test bar results comparable with the first one cited by Mr. Brophy, having 35 per cent reduction of area. My observation, including the examination of a great many tensile tests of welded bars, causes me to believe that this weld was extraordinary in the highest degree, and not characteristic of welds made by ordinary commercial methods in shops where there is every reasonable effort to safeguard the very important factor known as the personal equation.

It is my opinion, after a reasonable amount of experience that can come to one man who has, through the nature of his occupation, followed the progress of the welding art through its various states through the blacksmith's fire, the use of thermit, the employment of water barrel rheostat, the utilization of resistance grids, the development of motor generator sets, the generation and employment of gases for welding (up to but not including, as I am frank to say, the utilization of hydrogen with the arc), that the weld having a tensile strength of 49,000 lb. and a reduction of area of 15 per cent, which Mr. Brophy concludes was contaminated by poor quality of plate stock, is what would be termed "average good," and certainly not satisfactory indication, *ipso facto*, of a poor quality of the steel joined by welding.

There is no good reason why exponents of the art of welding should disguise from anyone the well-known fact that commercial welds are characterized by considerably lower ductility values than are typical of the material in commercial steel products as received from mill or foundry. There is no good reason why welding enthusiasts should obscure from engineers the established fact that the ductility values in welds of the same kinds of material when the equipment, the electrodes, and the operators are the same, are characterized by a very decided lack of uniformity in ductility values, wholly different from the values obtained in making tensile tests of the ordinary grades of steel marketed daily by mill or foundry.

My professional interests are commercially centered exclusively in the manufacture of small and medium-sized steel castings where the welding operation is advantageously but discriminatingly employed in the daily manufacture of the product. There is the keenest interest displayed by persons in the industrial class to which I belong, in the further development of welding operations. We sincerely hope that ways may be found to make available for commercial practice, welding methods that will give satisfactory uniformity and desirable ductility. If and when this happens steel foundrymen and ultimately the consumers of their product will be the gainers, because at present steel founders specializing

in high quality decline to take chances in welding serious defects.

Mr. Brophy, in commenting on the metallographic structure of welds and in speaking of the influence of annealing on a weld, states "it must be remembered that the metal is essentially a cast steel, so that annealing temperatures should be high and annealing time long to get the best results." It is incorrect to make the unqualified statement that the satisfactory annealing of a steel casting must include the application of the soaking temperature for a long time. Highly satisfactory results in normalizing and in otherwise annealing steel castings of moderately small sections have been obtained when employing the proper soaking temperature, under proper conditions, for no more than 30 minutes.

Without doubt those who purchase rolled, forged or cast steel for any purpose involving shocks or strains, should assure themselves that the material is of good quality. Mr. Brophy is justified in stressing this point, in the case of steel to be welded, if he will not allow his enthusiasm to lead him into comments that do not check with experience.

I hope Mr. Brophy and everyone else will understand fully that I am not making these comments for the purpose of offering sharp criticism. I have only touched on a very small phase of the paper that is of particular interest to steel foundrymen. I found the entire paper to be one of great interest. One portion of it, toward the last, which was but very briefly mentioned, aroused my keen curiosity. If there is time available, I would like very much to have Mr. Brophy, and possibly others, tell us something more about welding in alcohol vapor. Some of us, on account of past experiences of one kind or another, are a little bit leary about monkeying with hydrogen. Those who had any temerity on the subject of alcohol have seemingly lost that during the last two or three years, so we feel more disposed to play with alcohol now than we do with hydrogen.

I would like it very much if Mr. Brophy can give us some more information on that point.

Mr. H. L. Whittemore, Bureau of Standards: You have heard Major Bull's discussion. I wonder if Mr. Brophy would prefer to make his closing remarks after the next discussion. We have another discussion. You might include both of them.

Mr. James W. Owens, Newport News, Shipbuilding and Dry Dock Co.: I do not entirely agree with Mr. Brophy's conclusions relative to the effect of the base metal on the weld, for experience has shown that the physical properties of arc deposited metal are not the same as those of the weld metal in a joint.

Multiple layer metal arc deposited metal obtained by the building up of a pad has a much higher ductility and is softer in the central section of the deposit due to the annealing effect of the subsequent layers and the slower rate of cooling afforded the central section by the protection of the sections in contact with the

air and base metal. The tensile strength of the central section is slightly lower than that of adjacent sections. The air chilled section has a higher tensile strength but lower ductility and is harder than the section in contact with the base metal due to the heat being taken away very rapidly by the air. The greater the thermal capacity of the base metal, the greater will be the chilling effect on the deposit; consequently, the higher the tensile strength, the lower the ductility and the harder the metal.

I have obtained an ultimate strength of 72,000 lb. per square inch and an elongation of 20 per cent for a deposited metal specimen using bare low carbon steel electrodes. In my opinion, the rate of cooling and the annealing effect of subsequent layers has a greater effect upon the physical characteristics of the deposited metal than has the base metal.

I have contended for several years that better ingot iron and steel welds can in general be obtained with relatively high current densities than with low current densities, and I am pleased to note that Mr. Brophy has also reached the same conclusion. One of the principal advantages of high current densities is that it largely removes the human factor in welding as it insures positive penetration.

Mr. W. B. Miller, Union Carbide and Carbon Research Lab., Long Island, N. Y.: I would like to ask Mr. Brophy if the welds from which he took the photomicrograph showing the smaller grain size with higher current density were single run, double or triple run welds?

Mr. G. R. Brophy, General Electric Company: All made with single run welds.

Mr. H. L. Whittemore, Bureau of Standards: Has anybody else any discussion? We still have time enough, I think.

A Member: I would like to ask Mr. Brophy if he gets that migration of carbon from the parent metal to the weld when he just deposits one bead, or whether it is necessary to heat the whole of the metal up.

Mr. G. R. Brophy, General Electric Co.: A single bead will show that migration.

The Member: It shows it after annealing?

Mr. G. R. Brophy: It appears as such only after annealing. It does not show before, except that you get an indication of it from the light zone which I attribute to the higher carbon, causing more or less austenitic structure.

The Member: It certainly means that the carbon goes across there at a fast rate.

Mr. G. R. Brophy, General Electric Co.: When you stop to consider the temperatures involved, and the temperature gradient, you can readily see why it goes so fast.

Mr. H. L. Whittemore: Are you ready for Mr. Brophy's final remarks?

Mr. G. R. Brophy, General Electric Co.: I am afraid that I won't be able to keep them all in mind. But replying to Mr. Bull's criticism in which he makes the comment that we have not proven our case, I believe that the experiment with the fire box steel proves that. In the case of the low grade plate we got such poor quality and strength, and in the case of the high grade fire box steel such good strength with the same conditions of welding. I believe that that was proven.

In the annealing of castings his remarks are probably all right for a small casting. On the other hand, the weld is a small casting. I do not agree with him, however, that in such a short time as 30 minutes that the structure can be completely broken up. As a matter of fact, we find some welded structures which are almost impossible to break up, even after several hours of annealing. We attribute that to excess oxide in the weld.

Using gaseous shrouds or shields, the grain structure can be broken up very readily, in little more time than it takes to bring it up to temperature, whereas in the others they would not equiax even after 10 or 12 hours at temperature. I realize, of course, that steel castings do not contain the amount of oxide contained in the weld.

I would rather have some other General Electric man who is familiar with the shielded arc process tell about it. Perhaps Mr. Thompson will tell you about the hydrogen shield; he knows it better and can tell you better than I can. There is no particular advantage in using alcohol over hydrogen unless it is in the solubility of the two gases in the molten steel and the convenience. You may have more porosity with hydrogen than with alcohol.

Mr. M. Thompson, General Electric Co.: All I can say on that point is that with alcohol you can use a lower voltage than with hydrogen. I think that gives a little more stable weld, and, therefore, perhaps less porosity than you get in hydrogen. We have lately been using methynol and getting very good results on some classes of work.

Mr. S. W. Miller, Union Carbide Laboratories: I want to add, Mr. Chairman, the weight of my testimony to the fact that the plate has a distinct influence on the quality of the welded piece. It has not only been my personal experience, but it has been the experience of others in practical work.

About six years ago—somewhat over six years ago—I did a lot of work which was embodied in a paper read before the A. S. M. E. on fundamental principles of construction of unfired pressure vessels, a thing which you know has been one of my hobbies. During the course of that investigation I found very clearly, very distinctly, and very positively, that dirty plate will, in a zone next the weld, when it is heated to a temperature between the liquidus and solidus, cause rejection to the grain boundaries, of the dirt in the steel. It is perfectly natural that it should occur. The same thing occurs

in a steel casting which has not been worked. The result of that is, that in one case that I remember particularly, I traced a continuous film of foreign matter over two-thirds of the way through the plate. That was not in the weld, but was in the base metal 1/100th of an inch from the weld. In these cases there is a characteristic fracture of the test piece, parallel to the vee, apparently of a beautiful nature, and altogether looking like a very nice piece of metal. But if it is examined under the microscope, you will find that zone of dirt lying along the grain boundaries.

There is another particularly interesting case of that kind in the paper to which I referred, where the rejection to the grain boundaries has occurred a half inch from the edge of the weld. There is also plenty of evidence that where there is a dirty streak in the plate, the expansion, due to the heat, will force the melted material, which has a lower melting point than the steel itself, out; that it will lie along the edges of the vee, be dissolved, possibly by the added metal, and that, as it cools, it will crystallize out and form a line of weakness along the vee.

We have found, in some of our work, that the blame for the difficulties that we experienced, for instance, in welding tubes, was laid on impure oxygen. There was nothing wrong except that the metal was not suitable for welding. And I want to caution everybody not to use tank plate, where you expect to get satisfactory results in high strength work. Mr. Brophy is absolutely correct, in my judgment, that the best quality of material that you can get is the only material to use, and that, at the present time, is fire box plate.

I would be very glad to give the gentleman from the Bell Laboratories a list of references in regard to this work that he has been doing. I think we could find more in the paper prepared by Dr. Ruder and in the files of the American Welding Society.

There is another thing I want to speak of in connection with his paper and that is with reference to the figures he has given us, of which there are a large number. I can not recollect all of them, but I think the first one showed, if I recall correctly, that the tensile strength was of the order of 20,000 lb., and that the penetration of these welds was not more than two-thirds through the sheet. It looked to me as though they had not been beveled, the pieces had not been beveled.

Mr. Brophy: That is correct.

Mr. S. W. Miller, Union Carbide Lab.: I think we might as well forget in attempting to penetrate a 3/8-in. plate, with even 205 amperes and a 5/32 electrode. I do not believe it can be done.

I want to also emphasize this, that if you want high strength welds, it makes no difference what process of fusion welding you use, you should insist on double "V" welding. I can say with perfect confidence, because I have been following the matter now for a great many years, that I have never heard of and have never

seen a double "V" type weld that has failed under any circumstances at all. All of the failures that have occurred have occurred with a single "V" weld, which, in my judgment, is unfit for such stresses as we find in many structures.

I might refer particularly to welded tanks, in which the longitudinal seam is frequently a single "V" weld.

Mr. J. J. Crowe, Air Reduction Sales Co.: I would like to ask Mr. Brophy if he noticed any difference in the appearance of the fracture with the good welds and the bad welds. In other words, if it is oxide, you rather expect this fibrous fracture that Mr. Miller has just described, whereas if it is through the crystal in the good weld, you rather expect the crystal to fracture. I would like to ask whether he noticed that in the course of his observations.

Mr. G. R. Brophy, General Electric Co.: No. In all the welds I have observed, the fracture has taken place through the grain. Good welds, of course, will show a finer grain.

Mr. J. J. Crowe: Through the grain?

Mr. G. R. Brophy, General Electric Co.: Through the grain. Good welds, of course, will show a finer grain; they won't have that columnar grain; while the poor weld will show the large columnar grain.

Mr. J. J. Crowe, Air Reduction Sales Co.: It is true, isn't it, that if the oxide is present there, the chances are it would be thrown out to the grain boundaries, and you would get a fracture between grains in that case.

Mr. G. R. Brophy, General Electric Co.: In that case you would get a more fibrous fracture.

Mr. James W. Owens, Newport News Shipbuilding and Dry Dock Co.: I desire to take issue with Sam Miller on the question of single "V" welds. It is true that the double "V" weld is an excellent one and in my opinion should be used for material over ½ in. thick. Of course, it can be used for material less than ½ in., but the preparation of the joint edges would be more expensive. The reason why more consistent results have been secured with the double "V" weld is that the shape of the joint insures a throat section of the weld greater than the thickness of the material joined, as the weld is usually reinforced on both sides, whereas the bottom of a single "V" weld is irregular and rarely reinforced.

Test results have shown that if a single "V" weld is reinforced on the bottom, joints of 100 per cent may be obtained. Butt welds, whether they are of the single "V" or double "V" form, should be consistently reinforced on both sides if it is posible to do so. This should be regarded by the industry as standard practice. The amount of reinforcement will depend upon the average strength of the weld metal obtained with the filler metal employed. The height of each reinforcement should, in general, be about 25 per cent the thickness of the base metal.

Mr. S. W. Miller, Union Carbide Labs.: The only criticism I would

make of what Mr. Owen said is that he is making what I would call a double "V" type weld. It is the double "V" weld he is talking about.

Mr. Ernest B. Lunn: (Pullman Car & Mfg. Corp. Chicago, Ill.) I have had that same experience with double "V" welds. I found that where the specimens were machined in both cases the double "V" weld shows a much greater strength in every case.

Mr. H. L. Whittemore: Anybody else?

A Member: I have been very keenly interested in the discussion, especially where the matter of single "V" and double "V" welds was touched on. The emphatic remarks in which the tendency seems to be that the double "V" weld is going to be necessary for a commercial product is rather discouraging to me.

The experience I have been having in the last year leads me to feel that we should not give up readily this hope of securing a single "V" weld that will stand up and deliver the goods commercially, because there is an immense advantage to be obtained if we can do that. It can be done with a single setting; you do not have to turn the work or material over, your frame, or whatever you are working on, and, of course, you cut down the time.

We have been successful in our plant in putting out one type of apparatus with a single "V" weld, which is standing up in good shape. I do not wish to argue with the gentleman who has spoken just now with such emphasis, because there isn't any question that the single "V" if used is weaker than it would have been if we had taken the time to weld it on both sides. But the point I would like to get across is that if we do take the time to turn that structure over and re-weld on the other side to make a 100 per cent weld, or a 90 per cent weld, or whatever you may call it, we would have been so penalized in comparison with some of the other methods of construction that welding would have been lost and we might have been compelled to resort to some of the old conventional types of construction.

I had hoped that persistent study and experiment would develop a means of securing a single "V" weld which would be sufficiently strong to be a practicable proposition. I hope and believe that we will eventually obtain a weld which would be made with the edges of the materials that come from the shears with one bead run over it. I think we are too much inclined, in a society of this kind, to view the thing from the scientist's standpoint, and work out a refined structure to get an ideal result. If you are going to get anywhere commercially—and that is the ultimate aim of any such society—you have got to keep before you the idea of making it pay.

Mr. E. L. Sanderson; (Detroit) I have been in close touch with the Boiler Code Commitee, and I am quite sure, from my knowledge of the subject, and my contact with the committee, that if the society should stand for a single "V" weld, you will get no place. I personally cannot see how you can make a single "V" weld that

can possibly compare with the poorest kind of a double "V" weld that would be put on the market.

I might add, while I am speaking, that I have been doing a little work in improving welds. It is my opinion that one of the reasons why we have so many failures in the single "V" welds is that the weld metal is quite low in strength compared with the parent or base metal. You naturally would expect failure at the bottom of the "V". It is also difficult to get good fusion down in the bottom of the "V". My opinion is that a double "V" vessel is far more desirable than the riveted structure.

Some of the gentlemen may not know my connections. I have been in charge of boiler matters for the State of Michigan. I wrote the law, and for ten years I have had its enforcement in my hands. We have not had a boiler explosion in the State for five years, and one in Detroit for twenty-six years.

There is another feature that may have some interest and that is in the matter of the construction of boilers. The Code requirement calls for as much as 175 per cent of the plate thickness in the straps, due to the temperature and pressure, and now they have serious stresses along the edge of the straps. It is my opinion with proper progress that it will not be a great many years before welding, even fusion welding, will be allowed in high pressure boilers.

I might add, without taking too much time, a matter that is somewhat humorous. In one of the very largest plants in the city they recently installed a 1200 hp. boiler to carry 385 lb. They used an extra heavy 12-in. pipe, 1¼ in. thick for a circulating header, and they had four double extra heavy 6-in. pipes. They were welded. The operating load at operating pressure would be about 700 lb. per square inch. Under a strict interpretation of the Code, Section 186, that is not admissible, because the safety of the structure depends on the welding. With my authority I approved the construction on the ground that it was not violation of the Code, because it was not strictly a part of the boiler, but was an attachment on the boiler. The insurance company took the stand that I had no power to compel the insurance company to carry insurance that it does not care to, so they did not approve it, and they preferred them to carry the load in a manner satisfactory to the Code. So they took and built saddles and bolted them on, using special studs, ½-in. pipe size, and tapered, and they figured on plugging the hole at the same time holding the saddle at the head of the bolt. Well, I predicted that the thing would leak, and it did leak, and they had to weld up all the edges of all the saddles in order to make them tight.

Prof. C. A. Adams, Harvard University: In the welding problem there are not fifty-seven varieties of materials, but there are ten times fifty-seven varieties of jobs, and when a general statement is made it should be accompanied by such limitations as are necessarily required. If we have in mind those applica-

tions of welding where the last limit of strength and safety is required, that is one thing. If we have in mind another type of job where a fair degree of strength is sufficient, where the factor of safety is very large, that is quite another one. So that general statements about a single "V" and a double "V" weld are all mostly foolish.

Another thing enters in and that is, the treatment the weld is going to get after it is made. There are cases that happen to be of interest to me where some experiments have been made on the forging of welds, and the plates welded. I have a number of samples and tests made of these welds, single "V" welds on 2-in. plates, where they have been forged afterward, where the tensile strength of the weld was up practically the same as the plate, in some cases breaks occurred outside of the weld. Those welds, however, were worked, and the plates were worked mechanically, heated and worked after the weld was made. So that it is rather unsafe to jump at general conclusions.

There is no question in the wide world but that single "V" welds are going to be used in cases where the double "V" weld is practically impossible, and they will be entirely satisfactory if they are properly done, if, as I say, the requirements are not too great.

Mr. H. L. Whittemore, Bureau of Standards: One of the big achievements of the Welding Society is the fact that they have gone out and got information where it was needed. I think that they have done more of that than any other society that I know of. If some people believe that the single "V" weld can be made equal to the double "V", at least sufficient for certain purposes, if they will only prove it, get the data, we will all cheer their efforts. Have you anything to say, Mr. Lincoln?

Mr. J. C. Lincoln: (Lincoln Elec. Co., Cleveland, Ohio). I only want to say that the company I am with is specializing in carbon arc welding. In carbon arc welding the question of single "V" or double "V" is dealt with before we start. You have got to have a single "V" weld. In other words, the welding all has got to be done from one side.

The single "V", using the carbon arc process, has recently been used for building some 90 miles of pipe out in California. Each pipe was tested by hydraulic pressure to some 23,000 or 24,000 lb. per square inch before being accepted. While the pipe was still under the hydraulic pressure a number of heavy sledge hammer blows were struck along the seam about 1 ft. apart, half of the blows on one side of the seam and half on the other. That is a fairly good-sized job. It has been used now for some time. So that with a test of that sort it ought to be evidence of the possibility of making a single "V" weld commercially all right.

WEDNESDAY MORNING SESSION

President Farmer: The man who is going to preside at this meeting, I think, is well known to all of you. Mr. Deyoe is one

of the experts of the General Electric Company and is a director of the Society, and a member of the Executive Commitee, and I have much pleasure in presenting him to you at this time to preside over this session.

Discussion paper, **"The Use of Welding in Car Construction."**

Mr. J. W. Sheffer, American Car & Foundry Co.: Mr. Chairman, fellow engineers, I am sure it is a great disappointment to Mr. Willoughby in not being able to be present in person to present his paper. However, he has sent me as a substitute.

Chairman D. H. Deyoe, General Electric Co.: This paper of Mr. Willoughby's, which has been so ably presented by Mr. Sheffer, is, I am sure, very timely. All of us that are interested in welding should do all we can to assist the railroads in welding, because cars should be made lighter, more rigid and better fitted for the roads.

Mr. S. W. Miller, Union Carbide & Carbon Res. Labs.: I think possibly that more than some of the rest of you here, I appreciate this paper. I worked for a railroad for twenty years and I think I realize pretty well the difficulties that the railroad man is up against in the mechanical department. I don't think it is necessary for me to enumerate them; but I think I can say with truth that "once a railroad man always a railroad man." It gets in the blood and never gets out; and I want to say further that the training that I got on the railroad has been of inestimable value to me. If I had deliberately started out to get a good training in mechanical principles and discipline and in the other things that the railroads lay stress on, I don't think I could have done better than to go to work for a railroad.

I want to compliment Mr. Willoughby on the paper. It gives very clearly the position taken by the railroads in regard to welding, fusion welding, although I think that some of the statements that are made in it could probably be modified somewhat with advantage.

One of the greatest difficulties in railroad welding, or in welding on railroads, is the fact that Mr. Willoughby brings out very clearly—that railroads are not properly equipped as a general rule for good fusion welding. The interchange rules of the A. R. A. govern the movement of freight cars over every railroad in the country, and it is quite common for a car that belongs, for instance, to the Boston & Maine, to be away from the home line for a period not of days, but of years. Of course, the Accounting Department keeps track of the car, but the repairs to that car that are necessary may be made in the Far West. They may be even made in Canada; so that it is necessary—and I think we must all remember this—it is necessary to be careful how far welding is authorized by the A. R. A. rules which govern, as I say, the interchange of cars all over the country.

Some railroads do excellent welding. I don't think there is any

railroad in the United States that does better work than the Santa Fe. Those who are familiar with Mr. Purcell's work in that direction will, I think, agree with what I say. The work is done under procedure control, it is done carefully by trained welders, and the result is that the work that is done there is holding up.

But suppose that a Santa Fe car that has been welded gets onto the ABC railroad, down in the bottom end of Texas, somewhere, and something has to be done to repair that car. That railroad has no facilities for doing the work and the result is that any work that they may do in that direction is badly done.

I just want to mention one illustration of the kind of work that sometimes is done. Of course, you may smile at it, you may even laugh; but don't forget, please, that the railroads do have a tremendous regard for human life. They don't want to see anybody hurt, not even their own men; and if your experience had been the same as mine you would believe what I say. To any of you who are old railroad men, the explanation will possibly be quite clear. To others, it may not be.

A certain locomotive got so much side play in the driving boxes and rods that the inner flanges of the main rod struck the knuckle-pin, on one of the side rods. It was impossible at the terminal where the trouble was discovered to take up the side play in the driving box, which would have remedied the trouble; so somebody had a very brilliant idea. They took a cutting torch and cut out the flanges, top and bottom, on the inside of the main rod, so that there would be clearance between it and the pin. They did the same on the other side.

The locomotive started out with its train, and after it got along a little way the left main rod broke right through where the piece had been cut out with the cutting torch. The engineer disconnected that side and started off on one side with a reduced train. Twenty miles farther along the other rod broke.

Now, you may say that is ridiculous procedure; but don't forget that it is an actual instance. I therefore want to come, if it is necessary, to the help of the railroads and to say that they are justified in being cautious about applying welding.

On the other hand, it is their own fault that they do not use welding more. Let's look at the other side of it. Welding operations are so saving, not only in money but in time, that the railroads are missing a vital point when they don't train welders, in order that they might use fusion welding methods as they should. Hundreds of thousands of dollars are wasted every year by ordinary methods of repair that could be saved to the railroads if they would only use fusion welding methods completely and intelligently.

There are one or two things that I would like to speak of here: On page 15 Mr. Willoughby questions the use of the term "welding" for fusion welding, quoting the Standard Dictionary as au-

thority. There are many words in the English language that are not found in the Standard Dictionary, particularly in technical work. It is true that until fusion welding was developed, the word "welding" was confined practically to the joining together of ferrous metals by heating and hammering; but that does not make it any the less true that the term "fusion welding" is properly employed.

Fusion welding properly applied does make a sound, strong joint. In ordinary materials it makes a stronger joint than the base. I, therefore, feel that the desire of Mr. Willoughby to limit the term "welding" to welding that is done by heating and hammering or rolling is a little bit far-fetched. I think that he should admit that the term "fusion welding" is a perfectly legitimate one and that the work done by it, when properly done, is perfectly satisfactory.

It is also said that in order to rapidly attain the melting temperature, flux is used. Now, in all my experience I never found that any kind of a flux will increase the rapidity of the melting. The melting is not done with a flux; it is done with a torch or arc. I think, therefore, that that statement should be modified.

There is quite a little said about the Class V tank, and the statement is made on page 16, "This, as we understand the problem, is the basis of the opposition against the request now being made to the Bureau of Explosives of the Interstate Commerce Commission to permit the use of arc and gas welded Class V tanks." I would like to ask Mr. Sheffer what request that is, and who is making the request, if he is able to say?

Mr. J. W. Sheffer, American Car & Foundry Co.: Why, the proposition came up in getting out a sample tank, and it is a matter of going through not only the Interstate Commerce Commission, but this Bureau of Explosives; and in going through the Bureau of Explosives, they questioned the use of the fusion welding as against what they call hammering or forge welding.

Mr. S. W. Miller, Union Carbide Labs.: Was it a request for making a large number of tanks, or was it a general request?

Mr. J. W. Sheffer, American Car & Foundry Co.: A general request to begin and open up, so that you could get out a few tanks in service here and there. Of course, as brought out in the paper, they do allow special requests to come in, in the construction of experimental tanks; but this is a case of just widening out the opportunity to further push the fusion welding in tank construction.

Mr. S. W. Miller, Union Carbide Labs.: Well, it was news to me that any general request had been made for the use of fusion welding in the construction of Class V tank cars. I hadn't heard of it, and I certainly shall look into the matter a little bit more closely. I myself would not favor, as much an advocate as I am of fusion welding, the general release of fusion welding on all Class V tank cars.

I might say in that connection that we have in use in one of our plants tanks for holding propane, which is one of the gases mentioned by Mr. Willoughby, which are practically the same size as on the tank car, gas welded, carrying 200 lb. working pressure and tested to 600 lb. working pressure. We recently had occasion to move some of those tanks from one plant to another, across a river; and on account of their size and weight there was quite some little question as to how those tanks should be gotten across the river. So we finally rolled them to the top of the bank, which is about 75 ft. above the water, plugged the openings and rolled them down the bank, and towed them across the river, without any difficulty at all as to injury to the tanks.

I might say that one point that has to be seriously considered in the design of Class V tanks is the shocks that they get in service. They are full of liquid and heavy and the stresses on cars, particularly in a wreck, are quite serious; so that it is necessary to take the proper precautions.

I might also say that our tanks are a matter of routine production as far as we are concerned: we give the order to a shop that knows how to do the work and then we forget them. We don't even test them under our own supervision. They are tested by a commercial laboratory. I don't know how many of them we have in service, but it is somewhere in the neighborhood of thirty, and they haven't given us a moment's trouble. In none of the welds has there been even a pin-hole leak, under air-pressure and soap suds, so that they certainly cannot be accused of being porous or weak.

I do not know that I care to say anything more, except that the railroads must save themselves on this proposition. We cannot do it for them. They will, before they get done with it; they always have.

I can extend to any railroad man my cordial appreciation of the difficulties that he is up against, and I hope that the Lord will be with him in his endeavors to maintain and increase the high standards of railroad practise that exist in this country and the very great efficiency that so intimately is associated with our railroad life in the United States.

Chairman Deyoe, General Electric Co.: Mr. Miller, as usual, has brought out many very good suggestions for which we thank him. I have not personally had twenty years' railroad experience, but I have had experience in a period of three seconds, or maybe two or three more, which more than covers the purpose of impressing upon me anything that can be done to make a car more rigid —that is, in the case of an accident that it will either hold together or at least buckle, rather than to have rivet heads shear off and telescope—should be done, and we should help the railroads in every way that we can. A properly welded car will not shear apart.

Mr. L. M. Stewart, Gen. Boiler Inspr., Atlantic Coast Line R. R. Co. Gentlemen: You got talking railroads here this morning and I am in the railroad game and thought I had a little to say. Not on cars, though; I am in the boiler end of it.

I don't know of anything that has been more beneficial to the railroads than autogenous welding. We are calling it fusion welding now, because we use about 50-50 electric and gas welding. On our railroad, the Atlantic Coast Line, we have 1042 locomotives, and of that number there are 715 completely welded fire-boxes, no rivets at all, except in the mud rings. Some of those engines are carrying a working pressure of 225 lb.

We do various kinds of work. We have specifications and rules. We save many thousands of dollars a year in reclamation work. We don't buy new cylinders any more. When they break and crack they are welded—pre-heated and welded. We reclaim couplers and various things obtaining thereby great savings.

I happen to be vice-president of the National Boiler Makers' Association, and probably will have the honor of being president in 1929. I have been on the welding committee of that association for the past ten years. We work continually, all the while, to use welding and to get the best possible results. As I said before, it is one of the greatest labor-saving devices that was ever brought into a railroad shop. There are so many operations that can be done at much saving. In fact, I don't know how we could run a boiler shop any more without torches and electric welding. It is such an enormous saving.

We are getting splendid results. Most all roads have gone, to a certain extent, into welding. Some have been going into welding more extensively every year. We don't have the engine failures you used to hear about, the flue leakage and all this trouble—we don't have that any more. We weld our flues and fire-boxes. The consequence is, you don't have that trouble.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.: Problems similar to those of the railroads are encountered by me in the application of welding to ship construction. Indeed there is a greater chance of serious loss of life in case of weld failure on a ship than in railroad work.

In the application of welding, the shipyards are going slowly, but for the information of those connected with the railroads and others I want to say that decided progress has been made in the application of welding to ship construction within the last two years and the Navy Department and our company in particular are using it very extensively.

As pointed out by Mr. Miller, the definition of a weld as given in the paper is incorrect from a standpoint of modern welding practice. Welding can be classified under three principal processes—FORGE, PRESSURE and FUSION, the principal difference between these processes being that in *Forge welding* the weld

is in general completed by the application of a hammer blow; in *Pressure welding* by means of mechanical pressure, and in *Fusion welding* without any mechanical means. The temperature at which the metals are united also differentiates these three processes, for with few exceptions the metals are, in forge welding, in the plastic state; in pressure welding in the plastic or molten states and in fusion welding in the molten and/or vapor states. The definition of a weld which has been recently tentatively approved by the Nomenclature Committee of our Society is as follows:

> "The localized intimate union of metal parts in the plastic and/or molten states with the application of mechanical pressure or blows, and in the molten or molten and vapor states without the application of mechanical pressure or blows."

From this it will be seen that neither hammer blows nor pressure are necessary to obtain a homogeneous union provided the filler and base metals are in the molten and/or vapor states, hammer blows or pressure being only necessary when the base metal is in the plastic state.

The hammer weld is not necessarily the ideal weld that the paper would lead us to infer, for the scale and oxide on the surfaces which are joined by hammering remain and can be observed under the microscope. Regardless of what has been thought of the efficiency hammer weld in the past, it is not as high nor as consistent as properly made resistance and fusion welds, and if these remarks will tend to break down the prejudice of our older engineers against modern welding processes they would have been well said.

Relative to the use of welded containers for chemicals there is much yet to be known. There are, however, many such containers in service on which information can be secured. About a year ago we constructed a container for concentrated sulphuric acid in which all of the joints were metal arc welded. So far, this container has given entire satisfaction. Concentrated sulphuric acid does not cause rapid corrosion of steel, on the other hand such corrosion is induced by a dilute solution.

My experience has shown that savings can be effected in practically every item involved. There is, however, hardly any difference in the cost of driving the rivets vs. depositing the weld metal, except when caulking of the riveted joint is necessary in order to secure tightness and then there will probably be a saving in favor of the weld.

When the railroads get over their prejudice against welding it will be possible for them to effect tremendous savings not only in the useless weight that is hauled over the road bed daily, but savings can be effected in the manufacture of equipment and in the cost of its upkeep.

Mr. T. A. Wry, General Electric Co.: Mr. Owens what was the base metal in the tanks constructed to contain chemicals?

Mr. James Owens, Newport News Shipbuilding & Dry Dock Co.: I think it was the flange steel we use in our boiler work. I will have to check it up to be positive.

Mr. G. A. Caldwell, Mississippi Valley Structural Steel Co.: I just wish to ask a question. The gentleman from the Atlantic Coast Line made the statement that he welds the flues in boilers. I was wondering if they are welded at both ends of the flues.

Mr. L. M. Stewart, Atlantic Coast Line: Only the fire box end; that is all that is necessary.

Mr. E. Lun, Pullman Co.: I was very much interested in Mr. Willoughby's paper. I regret that he has not said more, or drawn some more definite conclusions in regard to the spot welding. Possibly Mr. Scheffer will say something in regard to that. The car referred to gave good service, I understand, and yet, so far as I know, it is the only car that has ever been built in that manner; and I wonder why.

One objection which is raised to the tack welding of cars is that question of the fatigue strength of the weld metal. Very likely that question will be taken up later, and it may not be advisable to bring it up now, in view of the lateness of the hour; but I would like to hear a word more about the spot-welded car.

Mr. J. W. Sheffer, American Car & Foundry Co.: This spot-welded car, as stated, was constructed in 1911. It was inspected at various times between 1912 and 1915 by the railroads. The reports from these inspections indicated that the car was standing up as well as other cars in the same lot which were riveted. Special inspection was made in 1920 which indicated that the car had been badly side-swiped at the top of the stakes and also at the bottom, but all the welds in the parts had held, except the corner brace, and on one of the lower door sheets an angle was torn loose. The inspection in 1925 indicated that although the car had been re-built in 1923, there still remained the greater portion of the original spot welding and this spot welding was in such excellent condition that it was decided to ship the car to Madison for photographing.

The one thing noticeable in the inspections that might be of interest, was the rust-resisting property of the spot weld. The welded sheets retained their original thickness at this point, but all metal immediately surrounding the weld was rusted the same as the remaining portion of the sheet. This is not the case in a riveted connection. Some one here may have an explanation. We have believed that the iron oxide on the sheet, when subjected to spot welding operation, hardened the steel and prevented it from corroding at the welds, leaving them projecting. If anyone else in the audience has a different interpretation of this phenomenon we would be glad to hear from them.

This we do feel, from the long years of service of this car: That it proves one thing—for car super-structures, sooner or later spot welding is going to come into its own.

I might also state that we know of two special designs of spot welded gondola and box cars that are under advisement. The ones interested in this proposition are trying to get a railroad which will agree to furnish the facilities to put into service ten cars. The design of these cars contemplates a series of channels, with flanges spot welded together, unit construction side, end and roof. There is no railroad and no car builder that has yet agreed to take up the plan. Perhaps the reason may be that those who control it are asking too much royalty or too much to sell outright. We believe that sooner or later, spot welding is going to come into very great use in the construction of freight cars.

Spot welding in passenger cars dates back to 1910 and was first attempted at the Berwick Plant under my supervision. Mr. Vom Steeg may be familiar—the first arc welding in our company was started under my supervision about 1913, and we are doing more welding every day.

Mr. Norton, Westinghouse Elec. Co.: There seems to be some misconception in Mr. Sheffer's mind as to what constitutes mill scale. There is not any silicon in mill scale, or there could not be any corrosive resistance. It is purely iron oxide, but a tightly clinging iron oxide is a rust resister; and your weld certainly has more of that, and with a very much more tightly clinging condition, than the plate itself has.

Mr. J. J. Crowe, Air Reduction Sales Co.: I would just like to make one remark about oxide. Mr. Willoughby's paper has inferred that the forge weld is free of oxide, whereas oxide is inherent in the fusion weld. I have examined a good many welds of both types, and I find that practically all steel contains oxide, so that it is a matter of comparative amounts of oxide, rather than being free of oxide or containing appreciable amounts. We found that it is possible, and I think Mr. Willoughby will agree, to make forge welds that contain oxide. I have examined a good many of them, and found appreciable amounts of oxide. Under proper procedure, I think we are all willing to admit that forge welds can be made without appreciable amounts of oxide. As the discussion here yesterday pointed out, it is also possible to make fusion welds without appreciable amounts of oxide, and a fusion weld properly made does not contain any appreciable amount of oxide.

Another point that Mr. Willoughby made was that one of the railroads welded some axles and several other parts, and after service they failed. I am a little inclined to think that those same axles failed before they were welded; otherwise they would not have been welded.

Now, just because a weld fails is no reason to assume that the weld has not been properly made. It may be a case of bad design, or of undue stresses on that particular member.

Mr. Connelly: I would like to ask Mr. Stewart, does he use an arc weld or gas weld on those axles, and whether he pre-heated or not.

Chairman D. H. Deyoe, General Electric Co.: Yes, I think it is rather a question of whether welding should be used on car wheel axles that are to go on the main road, unless they take the precaution of annealing after the weld is made. I think some of the railroads have tried it out, and some, perhaps, are using it; but I think that should be taken up very carefully.

Discussion **"Automobile Welding"** by Mr. W. C. Happ, Chief Engineer, Department of Methods and Standards, Studebaker Corporation.

Chairman D. H. Deyoe, General Electric Co.: Mr. Happ has given us a very excellent general treatise on welding, and I am sure from his paper that the Studebaker Corporation is making a very careful study of welding in all lines, and is advancing it as rapidly as possible.

We had the pleasure yesterday of taking a trip through a couple of the automobile factories here in Detroit, and it was certainly a pleasure to see the way in which the different methods of welding are being used in the manufacture of automobiles. We found all practises: Spot welding and gas welding on body work, butt welding together parts to form what would otherwise be an expensive and complicated forging, and arc welding on axle housings and torsion shafts.

Mr. Sudy: I would like to ask of the gentleman that just read that last paper, whether they had any depression in the spot welding, and if so how they overcame it. We manufacture a light line of furniture, and that is one of the things we have been up against.

Mr. W. C. Happ, Studebaker Corporation: I don't understand the question.

Mr. Sudy: We have had some experience where the spot weld would take place and there would be a depression, which would have to be filled up with a metal filler. I would like to know whether you have had that experience, and how you overcame it.

Mr. W. C. Happ, Studebaker Corporation: I would like to ask Mr. Roush, who is seated here and who is with our company, to answer that question. He has gone into that very thoroughly, and can probably give you some information regarding the subject.

Mr. Roush, Studebaker Corporation: I am glad to see where somebody else has had the same difficulty and fighting with it that I have had.

When we first started correcting these depressions made by the points of the spot welders, or the points that we use on the electrodes, we would take a little drill or a file and clean all the corrosion off the spots, then we would use acid to clean them and proceed to solder them, which was quite an expensive operation. We made up our mind that spot welding could be done without making those deep depressions, and we were going to do it. In order to do it I tried different points of all shapes and descriptions, but finally I

took a point about 1¼ in. or 1⅜ in. long, and about ⅞ in. in width, and made it perfectly flat. In the center of it, with about ½ in. radius, I cupped it out for about five to six thousandths deep. Now, the average spot weld you get from the manufacturer, has to have a little more pressure added; you have got to put a stronger spring on for pressure than they usually equip the machine with. By doing that and then by not trying to hurry your spot-welding too fast, it allows your upper point, being small, to come down on the depression, heats the metal and the metal goes down into this depression in the lower point. The piece is welded and is left practically as smooth as it was before. With the use of a buffing wheel or a disk grinder, just one or two strokes over, and you have a nice finished product without any depression.

That has been the only way and the best way that we have found to get rid of this depression. Always put the large part that is cupped out on the side where you want the good-looking job. Of course the under side, then, will have the depression, rather than the finished side.

Mr. M. C. Eckman, Ford Motor Co.: I am glad to hear these gentlemen talk on getting rid of the depressions on welds. We have had the same problem down in our plant for some five years, and we have used various means to meet it. I have a few suggestions to make on that problem.

In the first place, we built our own welders to get away from some of the trouble we had with the machines purchased from the outside. In building the welders we actuated the points or electrodes by pressure applied by cams. We found out that most of our depressions came from the metal pulling up at the weld, even with a flat electrode; so we put an extra hump on our cam and made it so that just at the time when the weld was commencing to cool off, this extra hump came along and gave us an extra push which flattened the indentation. We were compelled by necessity to put this little hump on the cams and shove the metal down right after the weld was made.

All our doors are spot welded, and we seldom have trouble with them. On these doors it is even more difficult to eliminate indentations, than on flat surfaces because of the bead. You have got to have an electrode to conform to this bead on the side where no indentation is allowed. The ordinary point or electrode on the other.

We also had trouble in our operators. The operators would hold the piece crooked even on this formed-electrode, they would hold it this way and that way, and up or down—some way that would cause a depression that we did not want. So we were compelled to do a thing that is not exactly right electrically, but you have to choose the lesser of two evils. We were compelled to make this formed point or electrode on which the work rested so that it would move in any direction; or locate itself. If the operator held the piece to one side, right or left or up or down, this piece would

align itself. It was a self-aligning affair, that has worked out very efficiently in our plant. We are using both those methods over the plants, in many operations.

Chairman D. H. Deyoe, General Electric Co.: Those are very helpful suggestions. Is there any other discussion? There must be many phases of this work that you can enlighten us on.

Mr. E. Lunn, Pullman Co.: Sometimes it is not possible to avoid a depression at least on one side and it becomes necessary to use some other expedient, especially on the softer metals like aluminum. The problem can be met very nicely, where you have the facilities, by spraying some metal on by the Shoop process and then grinding off the surplus material leaving a perfectly smooth surface and one that will take paint without showing any depression.

A Member: Mr. Chairman, I would like to ask what the thickness of the metal was in the steel car.

Mr. Sheffer: Quarter-inch plates.

Mr. J. C. Lincoln, Lincoln Electric Co.: What is the life of the ordinary car built by the riveting process? This welded car has been in operation now for sixteen years. What would have been the probable life of the car built at the same time with a riveting process?

Mr. J. W. Sheffer, American Car & Foundry Co.: I cannot say that there is any difference. It is a question of the sheets. One process does not increase the life over the other.

Mr. J. C. Lincoln, Lincoln Electric Co.: There is no corrosion that the rivets make?

Mr. J. W. Sheffer: It is the sheet itself that has to be replaced.

Mr. C. A. Bowlus, Chrysler Motor Corp.: I would like to ask the gentleman how extensively they have used the Shoop process in building up depressed surfaces and that sort of thing.

Mr. E. Lunn, Pullman Car & Mfg. Corp.: Our use of the Shoop process has been more or less experimental, but it worked so well that there is no question but what it is going to be very satisfactory on aluminum. It may work out well with zinc and brass and possibly other metals but we have not investigated them.

THURSDAY MORNING SESSION

President Farmer: The meeting will please come to order.

We have a program this morning which deals with a pretty important phase of the job that we have cut out for ourselves, in promoting the art of welding. Namely, the importance of the development of suitable designs for the efficient and effective application of welding.

The gentleman who is going to preside this morning is known to most of you. He is the Chairman of the local section of the American Welding Society, a mechanical engineer of prominence here in the city, and one of the excutive officers of the Barnes Wire

Fence Company. I therefore have particular pleasure in introducing to you Mr. W. C. Sprau, who has done so much to make our meetings here successful.

Discussion paper on **"Study of Oxy-Acetylene Welding as Applied to Light Gage Pressure Containers,"** by Mr. H. J. Grow, of the Air Reduction Sales Company.

Mr. F. E. Rogers, Air Reduction Sales Co., N. Y.:

I would like to emphasize one point that Mr. Grow brought out in his paper, in regard to the welding of longitudinal seams in pressure containers; and that is the ease with which the mechanical appliance or welding fixture can be applied for holding the sheets in position and absorbing the excess or radiated heat. If we could have such fixtures to apply to all forms of joints, the general problem of welding would be greatly simplified.

In welding the longitudinal seam in a pressure container, the excess heat and resulting expansion and contraction have given untold trouble to the beginning welder, and a great deal of the difficulty experienced in the early days of the industry was the control of this expansion and contraction. I think Mr. Grow has pointed out those difficulties very clearly, but perhaps he did not convey a full picture of what takes place in the welding fixture. With the substantial welding fixture, having a large mass of metal, the fixture acts as a radiator of heat. Sufficient pressure can be applied to the sheets at the joint to hold them with great firmness, —not so great, of course, that the sheets cannot draw together as the weld progresses, but sufficient to eliminate those minor movements which in the unsupported piece give a great deal of trouble.

We have found that it is possible to hold sheets with magnetic fixtures, with such firmness and increased heat-absorbing capacity that the sheets can be set absolutely parallel; but in commercial work, the necessary condition of accurately sheared sheets is seldom realized.

The ordinary plant fixture of the form illustrated takes care of sheets that are sheared with moderate accuracy, and while permitting slight movements thus it absorbs a large part of the heat and reduces expansion and contraction to a point where a fairly skilled welder can produce a one hundred per cent job.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.:

The semi-rigid joint featured by Mr. Grow, namely, one with edges angularly displaced prior to welding throughout the length of the joint, and which are permitted to gradually approach each other as welding proceeds, is one of the best types of joints to avoid dangerously high residual stresses in the weld. The reason for this is that as the joint edges approach each other during welding, no appreciable resistance to the cooling weld metal is afforded by the base metal.

A stress analysis of such a joint by means of strain gages has

shown me that there are high tension stresses in the weld metal at each end of the joint for a length of about 3 in. and high compression stresses in the section of the weld between these two high tension areas.

When gas welding is used, this type of joint is preferred and the reason that very few failures have occurred in tanks in which this joint has been used is that the heads of such tanks automatically reinforce the two end sections in which there is a high residual tension stress by strapping them.

There is a very important point that Mr. Grow omitted to mention and which I always stress, namely, the necessity of consistently reinforcing the weld. While this is only essential at the ends of joints of the semi-rigid type employed by Mr. Grow, it is absolutely essential throughout the entire length of joints of the rigid and fixed types in which the joint edges are tacked parallel prior to welding. I covered this point in one of my previous discussions today.

A form of joint shown by Mr. Grow, and which I do not think much of, is the lap joint when used as the flange for the head of a tank and in which the fillet weld is made at the point of curvature. In pressure vessels and vessels subjected to breathing, the stresses would be concentrated in the weld rather than in the base metal and tend to cause failure. The fillet weld should be located at least 1 in. from the curved section or knuckle, and the flange of the head should be made long enough to permit this. This is essential in pressure vessels and those subjected to breathing stresses.

Mr. H. J. Grow, Air Reduction Sales Co.: I wonder if I might say a word to explain the very excellent use of that type of joint in light gage work:

One of the big difficulties encountered in making up a satisfactory lap joint is to get good contact between the two members being joined. Light gage tanks are clumsy enough to start with, and are very difficult to size correctly so that the shell and head joint up properly. Where a head of that kind is properly crimped over, intimate metal contact can be secured; and the fact remains that the "leakers," as the job shops call them, will be very materially reduced, and it was shown for that purpose more than any other.

Mr. William W. Maxwell, Mt. Pleasant, Mich.: Occasionally we get welds on flat surfaces, and it is rather difficult to take care of contraction without causing distortion.

Is there anybody that can give me a little help on any procedure along that line?

Mr. H. J. Grow, Air Reduction Sales Co.: The butt welding of flat plate is essentially the same problem as the longitudinal weld in the seam shown in the first part of the paper. If those welds can be made in a similar manner, the job is very simple. If they cannot be, on account of the number, you have to resort to the rather rigid tacking, and the dissipation of the welding strains by some other

process entirely, either by limiting the amount of heat that goes into them, or any one of a number of schemes of that kind. It is sometimes found on a certain class of work that considerable straining must be done afterward.

Does that answer your question?

Mr. W. W. Maxwell, Mt. Pleasant, Mich.: We can allow for the contraction crossways, but a longitudinal weld is liable to make sort of a bulge.

Mr. H. J. Grow, Air Reduction Sales Co.: Yes, if the weld is not symmetrical, it certainly will. Your answer is to attempt to keep the welds as near symmetrical as you can, and if you can, the distortion is going to be minimized. Where the weld is eccentric in respect to the axis of the sheets, and that weld contracts, as it does when it cools, there is bound to be considerable plate distortion.

You minimize the distortion if you keep the sheets symmetrical with respect to the axis of the sheet.

Discussion paper, **"Welding in the Design of Steel Plate Work,"** by L. J. Sforzini, Engineering and Maintenance Department, Eastman Kodak Company.

Mr. J. E. Webster, Westinghouse Elec. Co.: I was very much interested in this paper, because it gives the use of welding in maintenance work, and changes in the factory. I represent the Works Engineering and Maintenance Department of the Westinghouse Electric Company. We have kept in close touch with our research engineers, so that the technique of the welding has been at our hands; and I will say that I have had our chief structural draftsman spend a considerable time in the welding school, and he in that way has become familiar with the exact amount of welding for any joint, and in the design work of our small buildings and changes, he has all information available to him.

You are probably familiar with the work that our engineers have done in testing all kinds of welds. Some of them are on exhibit at the convention; so that we have had that background. I won't go into any of the technique of it. I have prepared this little statement here.

(Reads paper printed elsewhere in this journal.)

Chairman W. C. Sprau, Barnes Wire Fence Co.: Speaking of structural steel buildings, our company has the honor of having the first all-welded steel building in the city of Detroit. It is a one-story steel building, and the steel was purchased from the mill, and never entered a fabricating shop. We did all the welding, taking the steel with the average mill tolerances and making a nice, complete job. I think we have a better building than we would have received with a riveted job, and it cost less money.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.: I was very much interested in Mr. Webster's discussion insofar as it related to costs.

tacking, and the dissipation of the welding strains by some other

I know of one company that went into welding on a fairly large scale some years ago and then stopped it because, as was said, "Welding costs more than riveting." Such experiences are seized on by our riveting friends to discredit welding without any investigation as to the reasons. If the substitution of welding for riveting does not reduce cost, there would be no sound reason for us to advocate it except possibly the production of a better product.

My experience has shown that there are many factors which influence the cost of welding and that each should be carefully considered in order to be assured of a saving. Good management, a properly trained technical organization, good design and the employment of sound technic are all essential to this end. Shop operations should be reduced to a minimum by ordering material neat, using the minimum number of punched or drilled holes, the avoiding of unnecessary bending and the hot working of parts by the blacksmiths and anglesmiths and by the use of assembly jigs. The maximum amount of work should in general be done in the shop in preference to the field, and those positions of welding used which insure a maximum rate of deposition. The largest sizes of electrodes and welding rods, the most suitable welding tips and gas pressures and highest current densities should be employed. Other factors which are frequently overlooked are that with a reduction in the total manhours required for the various trades involved, there is also a corresponding reduction of overhead, transportation and handling are less, a smaller stock of material can be maintained and expensive storage space for patterns is eliminated.

If welding is handled from the engineering standpoint and all factors are properly coordinated in order to reduce costs and secure high production, it will be possible to effect tremendous savings in industry by the use of the various welding processes, and it is up to the welding profession to see that this is effected and to counteract adverse propaganda by correct information.

Mr. H. J. Grow, Air Reduction Sales Co.: Welding the ends of pipe is essentially a rigid weld, particularly where the large-diameter pipe is considered. It is almost impossible, on the average job, to make any allowance to relieve the compression of the weld by purposely mis-aligning the joint to begin with, because of the difficulty that that sort of procedure imposes in the progress of the work.

I recently came from the welding of a good-sized line, where the question of the success or failure of the welded joints in the line involved the proper procedure in the welding, together with the relief of the strains that are set up where the weld finally finished.

Mr. R. G. Mason, Santa Fe R. R.: I think from your question that the pipe line you have in mind is probably of the smaller dimension and probably of a short distance; is that correct? You don't mean any thirty, forty or fifty mile pipe line? The pipe we put in the ground, say one thousand, two thousand feet long, we don't

as it related to costs.

take any precautions for the contraction or expansion of it, but just put it in the ground. We have not made any provision for the contraction and expansion of the pipe-line for the gases and steams that we have on the outside of the ground, as it is only about five or six hundred feet long. If the pipe-line is a little bit bigger, I have seen them put the horse-shoe bends in with provision for contraction or expansion.

Mr. F. E. Rogers, Air Reduction Sales Co., New York: Amplifying what has been said about the expansion of pipe-lines, I had a little experience on a line about six miles long laid a few years ago, near Niagara Falls, N. Y., for conveying hydrogen from one plant to another. It was a four-inch pipe-line. The provision for expansion in that line was "snaking"—a complete circle of pipe about 6 ft. diameter being inserted every thousand feet. Much of that line was laid through the fields, where it is exposed to the sun and great variations of temperature from summer to winter. That line has given perfect satisfaction. Hydrogen, as you know, is one of the most difficult gases to convey in a line. You have to have a perfect job; otherwise the losses will be tremendous.

Mr. H. J. Palmer, C. M. & S. Company, Trail, B. C.: There have been three points brought up this morning that I would like to have cleared up:

This gentleman speaks about opening his plate for welding in tanks, so that as he welds, the plate will come together. Another gentleman tells us about failures that he had had in his tanks, where the plate has evidently been laid close together and welded; while there is another gentleman here that speaks about reinforcing. Would the stresses that have been set up in the welding be duplicated again by reinforcing?

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.: My sizing up of the problem is this:

As the unit strength value of the weld metal is in general less than that of the base metal, therefore, the proper thing to do is to provide a greater section of weld area than that of the metals joined. If this is done, the unit working stresses in the weld can be made less than that of the base metal which is able to take care of them because of its greater ductility.

I usually use a unit ultimate strength of 36,000 lb. per sq. in. for the weld metal, although some designers are using 40,000 lb. One paper presented at this session showed a lap joint with fillet weld on only one edge. Such a joint is dangerous if subjected to bending stresses. In such cases a light continuous or an intermittent fillet weld should be provided on the second edge of the lap to prevent bending stresses occurring in the weld.

Mr. H. J. Palmer, C. M. & S. Company: I was just wondering if it would be advantageous to anneal the tanks afterwards.

Mr. H. J. Grow, Air Reduction Sales Co.: The question will require an involved answer. There is sufficient material for an en-

in the ground, say one thousand, two thousand feet long, we don't

tire morning's discussion in the action of the closure of the V-shaped opening on a long straight seam, versus the action where the seam is made rigid by tacking or some other method. I believe I am safe in saying that where it is possible to work a set-up that allows the plates to draw together when the weld is made, a final job will result where the stresses in the work are sufficiently low that no other precautions need be taken to further relieve them. On the other hand, particularly with gas welding, it is very common where the job must be welded as a rigid weld—that is to say, where there is no draw to the sheets as the weld progresses—to have to take precautions to relieve those strains, either by the application of local heating at the point where the weld finishes, or more extensive heating, depending on the facilities which are at hand.

Mr. L. J. Sforzini: The failure that I referred to in the paper was the failure where welding was in actual progress. In other words, it was a question of internal strain and not of external stress. Of course, you know when you obtain plates twenty-two feet in length and plus and minus a quarter of an inch, if the minus and the plus quarter of an inch are cumulative you are liable to have a one-half inch space between the plates at the end when you get through. Well, that was the case with the V-weld, and at the time we filled that up and completed the weld we got some cracks; but in the second method, where the lap welds were used, we did not even have a pin-hole leak or cracking of any kind.

Mr. M. L. Eckman, Ford Motor Co.: The discussion seems to have turned to pipe welding and as we have somewhere between fifty and sixty miles of welded pipe, from ½ in. up to 30 in., I think we have run into most of the problems in pipe welding.

There is just one thing I would like to bring up here that I have not heard mentioned this morning: We welded many thousands of feet of pipe, from 6 in. pipe down, by the resistance method. As you know, our company bought a great number of used ships from the War Department, and salvaged those ships, and there was pipe in them of all kinds and of all sizes. We welded that by resistance methods, and found it very good. We had some failures, but the failures were not due to the resistance method. Some of the pipe was laminated structure, and some of it was split, and much of it had flaws in it—worn material throughout.

But that is something for you to think about—it is very possible to weld by resistance methods quickly and efficiently.

There is the other method of welding pipe, by the fusion method. We do a great deal of that.

The gentleman spoke about breakage or cracks in welding pipe. We pick out a place where we are going to weld pipe, some place handy where the ground is more uniform, and we set up a series of rollers, place this pipe on the rollers, five or six joints, and we put a welder on each joint and he starts around it and gets to a place

quire an involved answer. There is sufficient material for an en-

where he cannot conveniently handle his torch. Then he calls out, and we just turn it over one-fifth or one-fourth turn, and he doesn't have much trouble as he is always welding in a natural position. Of course, that is rather common procedure. It is a matter of good, trained men, good material, and the job is very easily taken care of.

THURSDAY AFTERNOON SESSION

President Farmer introduced the chairman for the session, Mr. F. T. Llewellyn, of the United States Steel Corporation, whereupon Mr. Llewellyn assumed the chair.

(Mr. F. Matte reads paper on **"Arc Welding in Buildings."**)

Chairman F. T. Llewellyn, United States Steel Corporation: There were two points in Mr. Matte's paper which struck me very forcibly. The first was that a couple of years ago, when he started to investigate structural welding, he could not find fundamental data on which to base design. The existence of the committee on structural welding does not need any further vindication than that statement. In a year or two years time, I do not think that statement will be able to be made.

The second point in Mr. Matte's paper which occurred to me was the general rule that he adopted not to use field welding, unless there is an intrinsic advantage to be gained thereby. I do not wish to anticipate some of the papers that will be given later in the afternoon, but I suspect they will approach the question of field welding from a somewhat different and very interesting angle.

Instead of inviting general, open discussion of each paper separately, I am going to suggest that the discussion be deferred until the several papers have been presented. At this time I would ask is Mr. Davis, consulting engineer of Pittsburgh, here? Mr. Davis has a point with regard to structural welding that to me is rather new. I think he should receive consideration.

Mr. Charles S. Davis, Consulting Engr., Pittsburgh: I am not a member of the Welding Society. I am, however, deeply interested in the work that is going on, and I have been doing a little that will help welding along in a small way. I wish to thank the Society for the courtesy that they have extended me in allowing me to hear this discussion. I also want to compliment the last speaker on the pioneer work upon which he has been engaged.

I attended the meeting of the structural steel welding committee last evening, and after returning to my room a thought occurred to me of one feature that was being overlooked, and I attempted to put it on paper, so as to make it brief.

There is one feature in connection with the building of structural steel frames that should not be overlooked, and that is maintenance. It is of the utmost importance that steel structures be so built that it is practicable to protect them from such destructive agents as acid fumes and moisture. One of the most practical

a welder on each joint and he starts around it and gets to a place

methods is by painting. Those educated in the old schools like to see contact surfaces painted before assembling, as well as having exposed surfaces painted. There is a tendency to do away with the painting of contact surfaces before assembling. In riveted work, contact surfaces are so firmly bound together that the exterior coats of paint will seal all openings, and thus protect the contact surfaces from the corroding agents. But in welded work, I do not feel that the same protection is afforded unless the entire periphery of the joint is sealed by the weld. This means that stitch welding in many instances will not effect proper protection against rusting. For example, where a flange is composed of more than a single plate, or is made of plates and angles, or where a gusset plate is attached to a chord of a truss, rusting once started, between the separate parts of the member, in inaccessible places, would result in spreading the parts and eventually destroying the welds.

It is not my purpose to discourage welding, but on the contrary to encourage it, by having it so done as to be free from adverse criticism.

I might cite a case that occurred in my experience, which might illustrate some of the results of corrosion. In the neighborhood of 1900 the Eade's Bridge at St. Louis, a structure costing over seven million dollars, had been examined and condemned and the owners were advised to build a new bridge. As a result of this report a meeting of the owners was called—and by the way, the bridge is owned by fourteen proprietary railroads, or was at that time. As a result of the conference, a special committee was appointed to make a physical study of the structure, and as a result, repairs were recommended which could be made at an expense of not over two or three hundred thousand dollars, which would prolong the life of the structure many years.

Now, some of the faults in the existing structure were caused by rusting. Seven joints in the main arch ribs were rusted to an extent of there being play room in the joints of as much as one-eighth of an inch. Whether that rust was caused by salt water, by the action of decomposing coal, which may have fallen from loaded cars, and lodged in pockets at the joints, or whether it was by electrolysis caused by the electric wires leading to the harbor lights—we were never able to satisfy ourselves as to the cause; but there is this to bear in mind, that there are those decomposing elements to contend with.

In that case it is thought the cause was mainly salt water. The grade on the highway deck of the bridge was so great that in the case of sleet storms, and ice forming on the floor, traffic would be interrupted, unless salt were used and the ice melted. A trial was made to prohibit the use of salt but after the first sleet storm eighty horses were down in one morning and traffic was completely tied up. It was necessary to resume the use of salt.

There was another point that might illustrate what may be ex-

pected in the matter of rusting on interior surfaces. Holes were drilled through the main members of the arches, which were made of chrome steel, having an ultimate strength of 90,000 pounds to the square inch. Electric lights were inserted through these holes so that an inspection could be made of the interior surface. The surface was as perfect, so far as we were able to see, as it was a week after the structure was put in place. Attempts had been made to paint the inside of the tubes, with a spray, but this was not a success because our examination showed that the surfaces were not all covered. But in spite of that, there had been no rusting. It is the pockets and open places where the gases can get to it and where the water can get to it, that we must look out for.

Chairman F. T. Llewellyn, U. S. Steel Corporation: The next paper will be by Mr. G. H. Danforth, contracting engineer, Jones & Laughlin Steel Corporation. (Mr. Danforth presents his paper on **"A New Addition to the Arc Welded Building."**)

Chairman F. T. Llewellyn, U. S. Steel Corp.: The Society, I am sure, is very much obliged to Mr. Danforth for the very practical presentation of his paper.

Mr. W. C. Hopkins, who is in charge of bridges for the State Department of the State of Maryland, is going to describe the work that was done on the double decking of the Havre de Grace bridge.

Mr. W. C. Hopkins, Dept. of Public Works, State Roads Commission: Gentlemen, I am going to tell you about a bridge that we have back in Maryland that has some history. This bridge was started in 1860. The super-structure was finished in 1865. The superstructure was all wooden trusses. In 1873 the Pennsylvania Railroad, which built the bridge, decided to change the wooden trusses to iron trusses. The spans were approximately 250 feet. This work was carried along until 1878, when all of the wooden spans had been replaced by iron spans. The iron spans were on the old Phoenix iron section column, and some of them on the box section. The cost of the project was about five million dollars to the Pennsylvania Railroad at that time. The bridge was about 3300 feet long, 16 foot, center to center of the trusses. In 1904 the Pennsylvania Railroad built a new structure, adjacent to the present highway bridge, and the highway bridge was offered to the county commissioners of the two counties adjacent to this bridge. The county commissioners refused the bridge, and it was given to a group of citizens after the Pennsylvania Railroad had made changes in providing a new draw span and a new floor available for highway traffic.

The bridge went along for a number of years as a highway bridge, until automobile traffic increased, as it did, until 1923, when by an act of the legislature of Maryland, the bridge was purchased by the State Roads Commission. The highway bridge was earning net two hundred thousand dollars a year. Traffic has increased

yearly over this bridge until it is now having an annual traffic of about three hundred thousand machines a year, or, at maximum periods on Saturdays, Sundays and holidays of about five thousand automobiles a day.

The State Roads Commission was confronted with the necessity of providing additional facilities to handle automobiles over this bridge, and there were several schemes that were thought of. First it was contemplated to spread the trusses, as the roadway provided was only 13 feet wide. As the connection of the columns to the top chord was by the use of a cast iron member, it was not thought feasible to spread the trusses. It was also contemplated that possibly the trusses might be over-hung with additional roadway on either side, but that was discarded also.

The last thing that came to mind was the providing of additional deck, mid-way between the present lower deck and the top chord. The clearance between the top and bottom chords was 35 feet. So last September we awarded the contract to the Neeld Construction Company of Pittsburgh to provide an additional deck mid-way between the top chord and the bottom floor by the use of bolted connection angles to the vertical columns. After we had practically started the construction, Mr. Neeld made us a proposal that he would do the work at his contract unit price, if we would let him insert gusset plates in the columns to which we could attach the floor beams, the floor beams to be bolted and tacked welded, and the stringers braced by angle clips and also tack welded.

We investigated and found that we could save approximately 300,000 pounds of material, and we accepted Mr. Neeld's proposal.

(Mr. Hopkins continues with lantern slides).

Chairman F. T. Llewellyn, U. S. Steel Corp.: I don't think one needs any formal authorization to express to Mr. Hopkins the great pleasure and obligation the Society feels to him for having come from Baltimore to tell us about this unique application of welding.

Again, before opening general discussion, I think Mr. Candy has some slides on bridge work which we will have shown at this time.

(Mr. Candy delivered remarks illustrated with lantern slides.)

Chairman F. T. Llewellyn, U. S. Steel Corp.: I announced one surprise. I didn't know that we were to have two such surprises in this unique development of bridge discussion. There is such a wealth of constructive data that have been presented this afternoon that we cannot discuss them in full. It seemed necessary, however, to defer the general discussion until now on account of the length of the set program.

The meeting is now open for discussion on either of the topics that have been presented. I am sure that any one of those who have read papers will be very pleased to answer any questions that you might have.

Mr. J. J. Crowe, Air Reduction Co.: There are so many points

that have been brought out in those two papers that are being discussed frequently in the committee on structural steel that I think a little description of the work that is being done by the structural steel committee by our genial chairman would certainly be in order.

Chairman F. T. Llewellyn, U. S. Steel Corp.: A year ago the structural steel welding committee was organized for the purpose of presenting to the structural steel industry a series of unit values upon which design could be based with any given factor of safety. In general they found a large number of tests had been made on butt joints, but in few cases did those tests give unit values. There were many cases where the weld, particularly a reinforced butt weld, had outpulled the base metal. By base metal is meant the metal that you unite together. The base metal had gone rather than the weld. Some of our welding friends thought that was all that was necessary, and that it afforded the structural engineer all the information he needed, overlooking the fact, perhaps, that there are many cases where, in structural design, you do not need to develop the full strength of the section you are uniting—for example, the full tensional strength of a column. It is very seldom that a column is subjected in compression to its full tensile capacity. Now, how big are we to make the connection of that column? We must have unit values.

We therefore laid out a program involving over a thousand tests, accompanied by a procedure specification covering the qualification of welders for the making of the specimens, these qualifications not being unduly severe, but such as to give what might be expected in commercial work. The procedure specifications also cover inspection and method of testing. A list of specimens has been prepared in detail. It involved a few uncertain items. We were not sure just how some factors would work.

With few exceptions the specimens were designed to break in the weld rather than in the base metal. In order to straighten out some of the open questions with regard to these specimens, 342 pilot specimens have been prepared, with the cooperation of Prof. Peter Gillespie, professor of engineering in the University of Toronto, to whom this Society is indebted for invaluable work. A portion of these specimens were welded by the gas method; a portion by the arc method; and a sufficient number of them have been already tested, to indicate that some very valuable information will be available very shortly.

As a result of these pilot tests, the committee on structural steel welding will make a few minor changes in some of the specimens they proposed to test—that is, on their large program. The plan is to have these specimens prepared by shops throughout the country. A surplus of shops have offered to prepare specimens. The last list I saw there were nearly a hundred. We must limit the number to about twenty. All the steel has been donated by various steel companies. In fact, no steel company has been asked

but what they agreed to donate steel very readily. The funds needed for carrying on this work, it was reported last night, have been pledged, so that that work may be expected to proceed very rapidly. I can hardly prophesy that within a year results will be complete, because we have a large program, but within the next year or two there will be some valuable data, as to the unit strength of welds, made by the fusion process under all ordinary conditions.

Mr. Spraragen: Mr. Chairman, in connection with Mr. Matte's paper, there were some test results shown that were made in Detroit. I would like to point out, in connection with this structural steel investigation that we propose to carry out, that one of the first things we are going to do is to test the welders to make sure that they are qualified to do work as important as structural steel work. The limits that have been set are regarded by the committee as quite reasonable. Comparing those limits with the test result shown in Mr. Matte's paper, a number of welders in one shop would not be allowed to weld on our structural steel investigations. The test results that could be obtained with low carbon wire or medium carbon wire of the American Welding Society's specification would easily give 10,000 pounds per square inch stronger than that shown in Mr. Matte's tables with an average good weld.

Chairman F. T. Llewellyn, U. S. Steel Corp.: I was wondering what reaction there is to the point Mr. Davis raised regarding the possible effect of corrosion on the faying surfaces (i. e., contact surfaces of joints) when intermittent or tack welds are used and the space between is not covered by paint. We all remember that under the old specifications for structural steel assembled by the riveted method there was a clause, "All surfaces in contact prior to erection shall be given a coat of paint."

For your information, the standard specifications for all the steel buildings that are put up by the company that I happen to be connected with contain a clause that reads, "No paint shall be used on contact surfaces of steel assembled prior to erection."

I do not think we are alone, but I mention it because we have gone to the length of absolutely forbidding paint, and for this reason: We found that in many cases where paint was inserted between such faying surfaces, tight rivets were impossible. We had a very undesirable experience on crane girders, due evidently to loose rivets as a result of the inner surfaces being separated by paint. We are getting very much better results now that we forbid the use of paint there; but if the use of paint is forbidden in such places, and the welder wishes to economize by making his welded joints intermittent rather than continuous, what is going to happen as to corrosion on such surfaces? It is a real point that I think we should consider.

Mr. E. Lunn, Pullman Car & Mfg. Co.: I fail to see why we cannot make as tight a joint when we weld as when we rivet, if proper attention is given to the preliminary clamping.

Mr. J. Matte, Albert Kahn, Inc.: Mr. Chairman, I think it might be possible to make a slight change in the design in the case that Mr. Davis brought up, and instead of having one-half inch tack welds, to use a small continuous bead like a quarter inch bead, and substitute that for the tack weld. In that fashion you would have practically the same amount of welding, and it would eliminate the gaps. That might be, perhaps, one solution. Even, however, with the tack welding, I would be under the impression in general that with a little additional care enough paint could probably be inserted above and below the tack to get a fairly good protection.

I think that Mr. Davis has brought up a point that is certainly worth while bearing in mind. There is no side-stepping it; something particular must be done in connection with it, but I do not think, however, that it is an insurmountable objection, and I think it can be met with a little additional care. I was very glad to hear that point, because I think a good many of us might have overlooked it.

Chairman F. T. Llewellyn, U. S. Steel Corp.: I would like to ask a question of Mr. Hopkins or Mr. Neald, in connection with the welding of the Havre de Grace bridge. They were working there on old Phoenix columns made of wrought iron, real iron as they used to make it in early days. Today our welding is largely with a structural grade of steel, and mostly open-hearth steel. Was any difference found in the behavior of the weld connecting to the iron, as opposed to the steel that we are using today?

Mr. W. C. Hopkins, State Roads Commission: Not a bit, sir, not a bit. In connection with what was brought out regarding painting, we did as the last gentleman suggested, we used ¼-in. weld, and where our gusset plate was slotted into the vertical post, we used ¼-in. weld on all the four intersections. Of course, those columns were water-tight, and investigation of the inside of them showed no deterioration, no rusting whatever, no corrosion at all. They had a small leak hole at the bottom of the column that drained the column, and our slotting the post and running this ¼ in. bead weld all around the intersection, of course, closed the slot up entirely.

Mr. J. Matte, Albert Kahn, Inc.: Mr. Chairman, your last question, regarding welding of pure iron, brings out this question from me: Will the structural welding committee make some tests on the results of welded silicon steel, since this is beginning to be a material more extensively used?

Chairman F. T. Llewellyn, U. S. Steel Corp.: The committee has passed upon that question and has authorized the following program: The bulk of the material tested will be open-hearth steel of structural grade, to ASTM specifications. Material from each mill is to come from a minimum number of melts, so as to eliminate, as far as we can, any question regarding the behavior of the steel. We are not testing the steel; we are testing the weld.

At the time when orders are being placed for standard struc-

tural steel, we are authorized to advise the mills that where they can duplicate the sizes in question in copper-bearing steel and silicon steel, to do so. We expect to be able to have tests on silicon steel for a number of specimens, but probably not for every type.

There was an apparent contradiction—you doubtless noticed it—between the point that Mr. Matte presented in the first paper of the afternoon and the description that we received by Mr. Danforth in his paper, entitled "A Recent Addition to the List of Arc Welded Buildings," Mr. Matte's rule was—I am paraphrasing it—use welding in the shop fairly freely; do not use it in the field unless there is some intrinsic advantage to be gained thereby. On the building that Mr. Danforth reported, the only possible advantage I can conceive of for riveting in the field was economy, and apparently the company that Mr. Danforth represents, and the owners for whom they were doing the work, found that in that case it was economical.

Mr. J. E. Webster, Westinghouse Electric & Mfg. Co.: Mr. Danforth in his paper stated that if he was to do the Derrick Building again, he would take all of the steel directly from the mill. I wondered if he would state what effect that would have had on the cost. Would he have saved very much more?

Mr. Danforth: Well, I will say, Mr. Webster, that it would probably have cut the cost possibly $1 a ton.

Mr. J. E. Webster, Westinghouse Electric & Mfg. Co.: I gave a little discussion this morning on the paper of the gentleman from the Eastman Kodak Co., and I mentioned in that that we had built several buildings at East Pittsburgh entirely welded, and we had put additions on other buildings involving quite considerable tonnage. They are not large buildings, but they are very much the same class as the building that was built at Dorry; and in every case we have purchased the steel directly from the mill and have done all of the necessary fabricating on the ground, in that way cutting out all shop work. This we consider a big asset, especially for a concern that wants to get a job done with the least difficulty, cut out a lot of drawings, and you find the erection work goes right ahead.

Chairman F. T. Llewellyn, U. S. Steel Corp.: The building that Mr. Danforth described was a one-story building, 20 ft., as I recall it. Your buildings have all been about that height?

Mr. J. E. Webster, Westinghouse Electric & Mfg. Co.: We built a one-story building that was rather higher than this one, carrying a 20-ton crane. We also added to our chemical laboratory, which was a two-story building, by putting one additional story on it, and extended the whole building about 40 ft. in length—the three stories.

That work was all done in the field. All steel cut mill lengths, with mill tolerances, and the fabrication all done by the erectors.

Mr. A. G. Bissel, Westinghouse Electric & Mfg. Co.: In the build-

ing Mr. Webster spoke about there was not a bolt used in putting that building up.

Mr. Llewellyn: That is very interesting.

Mr. J. Matte, Albert Kahn, Inc.: The building that Mr. Danforth speaks of is a low building, and the buildings that Mr. Webster speaks of are also low buildings. The building that I was alluding to is 40 stories high, and I have an idea that the main reason why Mr. Danforth and I do not quite agree is that we are talking of very different types of buildings.

In a one-story building the columns, as I observed on Mr. Danforth's slides, are set on top of the beams or trusses. That means that the end of the beams would be tacked there. In a multiple-story building, naturally the beams have to frame to the face of the column, and the amount of welding that is involved is very much greater. I assume that the fact that there are many more lineal feet of weld required in a building such as I happened to pick out as an example, is really the fundamental reason why there is an apparent disadvantage instead of a net advantage, as Mr. Danforth reports.

There is also another point: A one-story building would frequently be erected at a cost of perhaps $15 to $18 a ton. That is the price, not necessarily the cost price; that is what the contract would be awarded for. A multiple-story building, on the other hand, on account of the heavier tonnage, the greater tonnage, would be very often put in at from $14 to $16 a ton. The particular job I picked out was awarded to an erecting firm for $15 a ton. Now it is to be observed that the division of cost for the various parts of the work which we include under the general caption, "Erection," are not the same for a low building and for a tall building.

Mr. Danforth reports that the cost of welding amounted to $7 a ton for that particular building, and since that cost of $7 a ton resulted in an economy for his company, it means that the cost riveted would have been more than $7 a ton. In the case of the multiple-story building I have in mind, I took the pains to inquire from the company who actually had the contract for the erecting in order to get the division of their costs. They had only allowed $5 a ton for erecting the steel. Well, now, if it had cost them $5.50 a ton to weld it, they would have been out of pocket. It would have been absolutely necessary for them to be able to weld the job for less than $5 in order to show any economy, because, naturally, their handling costs, their hoisting costs, their cartage costs—that is, handling—would have been the same regardless of the method used. They made a little money, I am sure, on the basis of $5 a ton. Now, if it had cost them $7.50 a ton to weld it, which is exactly the figure Mr. Danforth has quoted, they would have lost a lot of money.

So I imagine it is going to require more study than has yet been given to the subject to ascertain just when welding should

be used and when riveting should be used. Mr. Danforth's example is a very fortunate one, because it shows that the statement I made is in general true, as the majority of the big jobs are tall jobs; but at the same time in one-story buildings that statement may not always be true. It would be wise for structural engineers who happen to have such jobs to get a price for welding from the Jones & Laughlin Steel Company and others who have had experience in welding one or more one-story buildings. In that fashion the fact that it is or is not cheaper than riveting will be clearly shown.

Chairman F. T. Llewellyn, U. S. Steel Corp.: I believe a building was put up about a year ago by a welding concern in Youngstown. It was a one-story building, erected along very much the same lines as the Jones & Laughlin product; that is, practically all, if not entirely all, of the welding was done in the field, and with success, I believe.

Mr. G. H. Danforth, Jones & Laughlin Steel Corp.: Right there I might say this: That when you come to the taller building, I am sure that at the present time I am not an advocate of welding, but I do know that there are hundreds of buildings with a tonnage ranging from 200 to 500 and 800 and possibly even 1000 tons of the one-story type wherein there is a decided economy in welding.

Mr. E. H. Ewertz, Consulting Engineer: I know but little about the various elements that enter into a building and the fabrication of same and therefore naturally have no right to talk with any authority on building construction. The discussion here has brought certain thoughts to my mind that may be worth considering in connection with the application of welding to structures.

By welding a structure it is possible to save considerable of the weight of steel, and therefore the saving in material may be of sufficient margin, even though no saving could be accomplished by welding over riveting, to make an equally good, but cheaper construction job.

Regarding the question of paint, a riveted joint may be a tight joint after its fabrication, but we know that it takes very little vibration to slacken it up and what was originally a joint of metal to metal now becomes a joint of metal air and metal, and air provides the means of corrosion providing no other means were taken to protect the metal surfaces, on the other hand the welded joint is rigid and will either stay rigid as originally made or else will fail and break, therefore the painting that you may do around a welded joint would continue to remain the same as originally produced, and under such conditions it is very easy to seal up even with paint any small crevices as long as those crevices stay in their original form.

Mr. A. G. Bissel, Westinghouse Electric & Mfg. Co.: I might verify Mr. Ewertz's statement in regard to these vibration tests we ran a couple of years ago. The specimens were all painted, and around the welded joints there was no cracking of the paint on either side until the specimens themselves failed from fatigue,

while around the riveted joints, in 5 minutes the paint along the cracks had failed and you could see the members start to shift, showing dust coming up in back of the joints.

Mr. Neald, Neald Construction Co.: In regard to that vibration, we made a pile-driving cap by electric welding, making a ring and welding together at the joint. Then put a ¼-in. plate over the top of it and we drove some 125 piles with that, with a No. 7 pile hammer, under very hard driving, before it showed any signs of giving, and then the lower ring broke through—I don't know whether at the weld or at another point. Then it worked itself through, but we thought it showed a marvelous resistance to vibration under the service that it stood.

Mr. E. Lunn, Pullman Car & Mfg. Co.: I wonder if any thought has been given to the effect of fatigue on the metals in welds in building construction?

Mr. W. H. Himes, Westinghouse Electric & Mfg. Co.: In protecting the interior air space where it is not covered with paint and you want to use an intermittent welding system, it occurs to me that it might be practical to run around the interval with a caulking hammer and insure a real tight job before painting between welds.

Mr. A. G. Bissel, Westinghouse Electric & Mfg. Co.: I believe that what we call a shoe string weld, which is a very thin weld, put on with a fine wire, which would be cheaper than caulking. In fact, they could be put on first to seal your member and then the heavier weld put on there. That is the practice we use in ship construction. In welds I have seen in salt water, which had been in it for years, as a matter of fact, there was no more corrosion on the weld metal than there was on the plate, except where you had corrosion from rivet heads due to electrolysis between the bronze propellers at the stern and the rudder or steering post; but on the bow end we found no corrosion at all in the weld.

Chairman F. T. Llewellyn, U. S. Steel Corp.: Considerable attention has been given to the subject of fatigue. I am not particularly posted on that phase of it, but believe that Lloyds register of shipping, which is a very conservative organization regulating the construction of ships on which they are willing to authorize insurance, made a number of fatigue tests. Perhaps Mr. Ewertz is posted. As a result of their tests I think I am correct in saying that they allowed welding on ship construction to a very large extent. Is that correct, Mr. Ewertz?

Mr. J. Matte, Albert Kahn, Inc.: Answering that same question from a structural engineer's point of view this is the way the matter of fatigue struck me: Since locomotive frames are welded, and any one who has ridden locomotives has observed that they are subjected to a terrific vibration, we are entirely safe in using welding on buildings where the vibration is so little compared to that of locomotive frames.

Chairman F. T. Llewellyn, U. S Steel Corp.: Might I throw out

a remark from a slightly new angle that perhaps bears on the question. It is a thought that I expressed at a joint debate of the society in Philadelphia last spring. The debate was between the advocates of riveting and the advocates of welding—quite keen but kept on a high level throughout. Great emphasis had been laid by the advocates of riveting on the low ductility of the material deposited in a weld. There is no question but that its elongation is less than that of the base or parent metal. If we say the parent metal has an elongation of 20 per cent in a length of 8 in. we might expect to find 5 or 6 per cent in ordinary deposited welds, or butt joints, and a great deal was made of that; and as this gentleman talked, I stopped to think, "Elongation, 20 per cent; reduction of area 35 per cent, or whatever the specification calls for; what does that mean? When we put the steel in a building do we stretch it 20 per cent? If we do, it will be useless. Do we reduce its area 30 per cent? If we do, it will be useless."

Evidently, elongation and reduction of area, all such properties, all those characteristics that we commonly summarize in the word "Ductility" are not usable in themselves. How, then, are they useful? I take it the prime purpose of ductility tests is to determine the reliability of the metal. You get my point? Now, if that is so, is it necessary that your deposited weld have the same characteristics as the material that it is joining, provided the entire structure is reliable?

Let us take a bridge or a building—a high building. We are accustomed to specify that the steel shall be ASTM standard, and the rivets shall be ASTM standard, and we commonly think of the structure as therefore homogeneous. Well, there may be a question as to whether it is homogeneous, but let that go. However, carry that structure down to the foundations, where it may rest on cast steel bases. A weld is cast steel. They used to employ cast iron bases with entirely different characteristics.

Your building is not unsafe as a result of having different characteristics in your base plate from what you have in your upper framework, provided your base plate is big enough.

Go still further. Below your base plate (today we are using slabs very largely) below that you strike the concrete foundation. The ductility of concrete, you cannot find it (Laughter), and yet it is an essential part of your structure, on which the stability of the entire structure depends.

Do we, therefore, feel doubtful about the stability of our structure because those component parts have different physical characteristics. Not if you make your concrete foundation big enough.

Go still further; your concrete foundation rests ultimately on the earth, clay or rock, by means of piles, or spread—who knows what is the ductility of the earth? And yet we have no doubt as to the stability of the entire structure provided the bearing is big enough.

So, as I see this problem, it is not primarily a question of whether the deposited metal has the same physical characteristics as the base or parent metal united, but is it big enough and reliable enough to perform the duty that is imposed upon it? And the answer to that question will be given to the industry in unit terms by the structural welding committee of this society within the next year or two. (Applause.)

If there are no further remarks or questions the meeting will stand adjourned.

(Final Adjournment.)

Electric Welding in Maintenance*

By J. E. WEBSTER,†

Electric welding has, by its own merit, worked its way into our maintenance department until we now have four operators and four portable welding sets. The work done is largely new work or additions to existing structures.

One of the difficulties to overcome in getting efficient main-

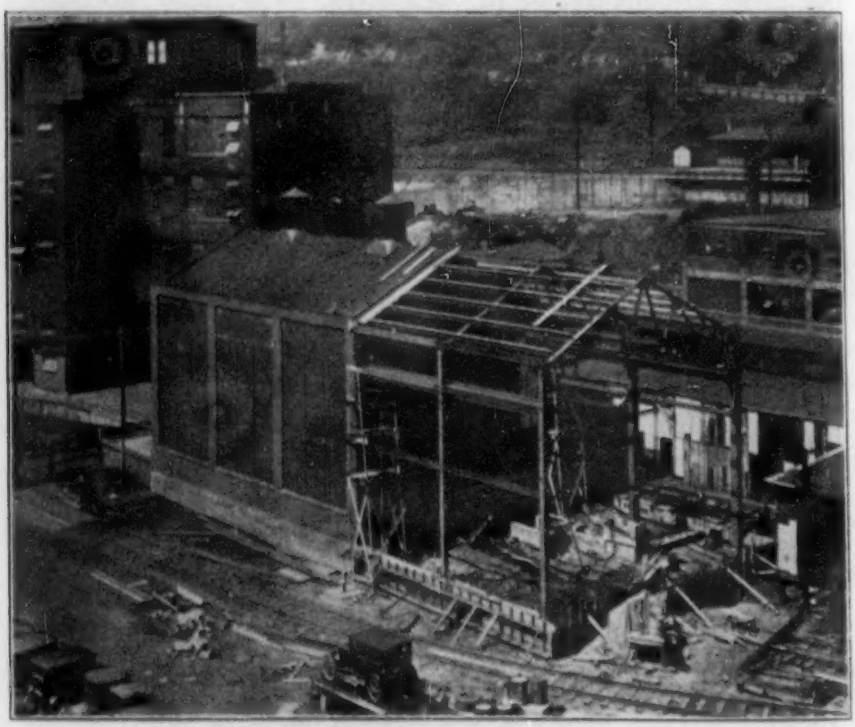


Fig. 1—Addition of two bays to an existing building

*Discussion before Fall Meeting of American Welding Society at Detroit, Mich., Sept. 22.

†Works engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

tenance work is the great variety of tradesmen required to complete a given job. In order to overcome this we have for years done a lot of steel erecting with our carpenters, but until welding came in detail drawings were necessary and the steel had to go through the fabricating shop.

Since using welders, however, it has not been necessary to get as accurate measurements and hence a great saving is made of the draftmen's time and also the big chance of errors in dimensions of the fabricated steel have been avoided. Drawings, of course, are made showing sections of steel to be used and welding required.

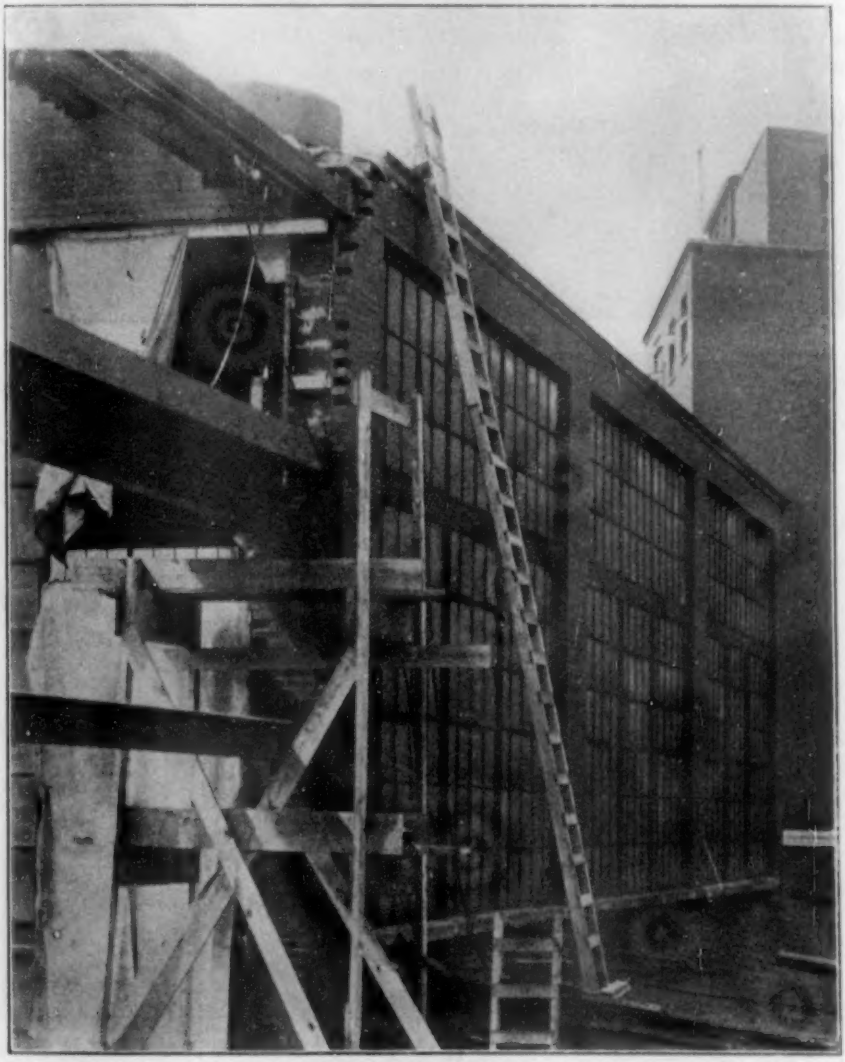
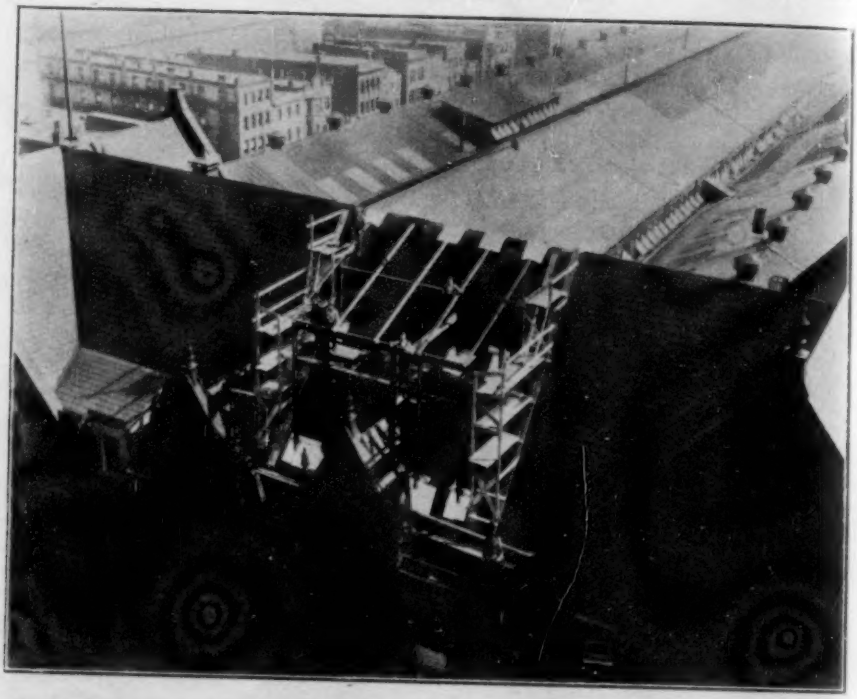
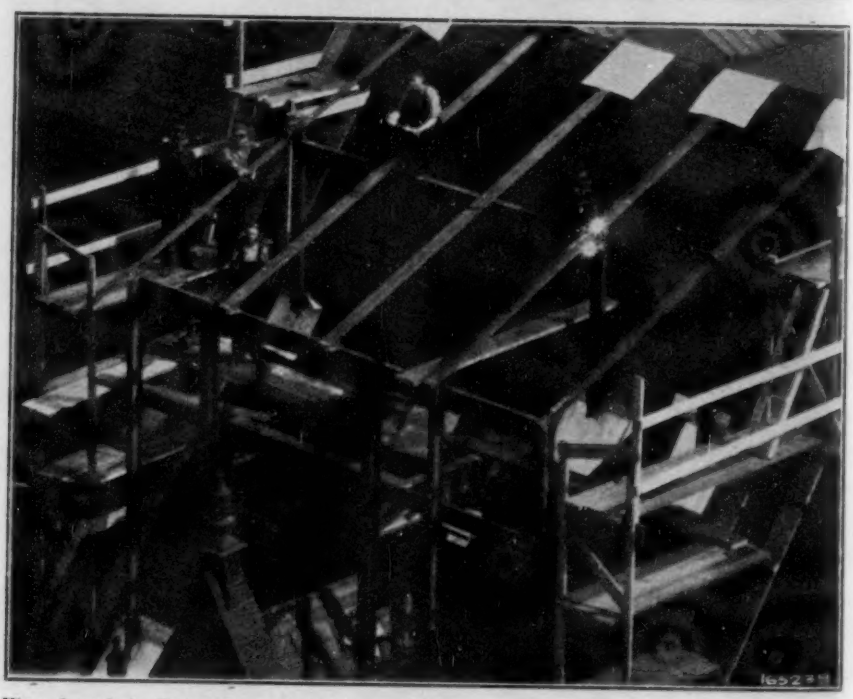
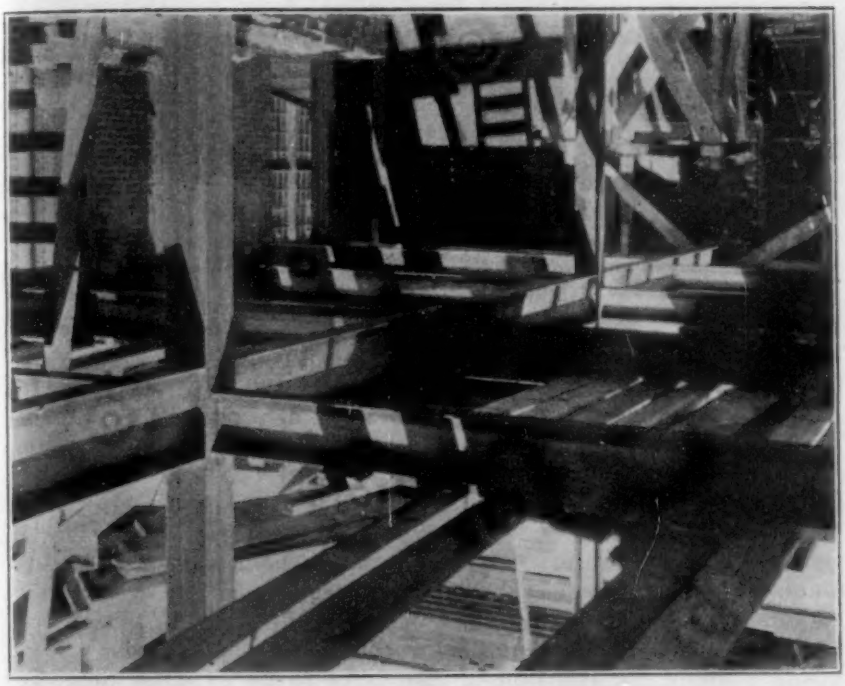


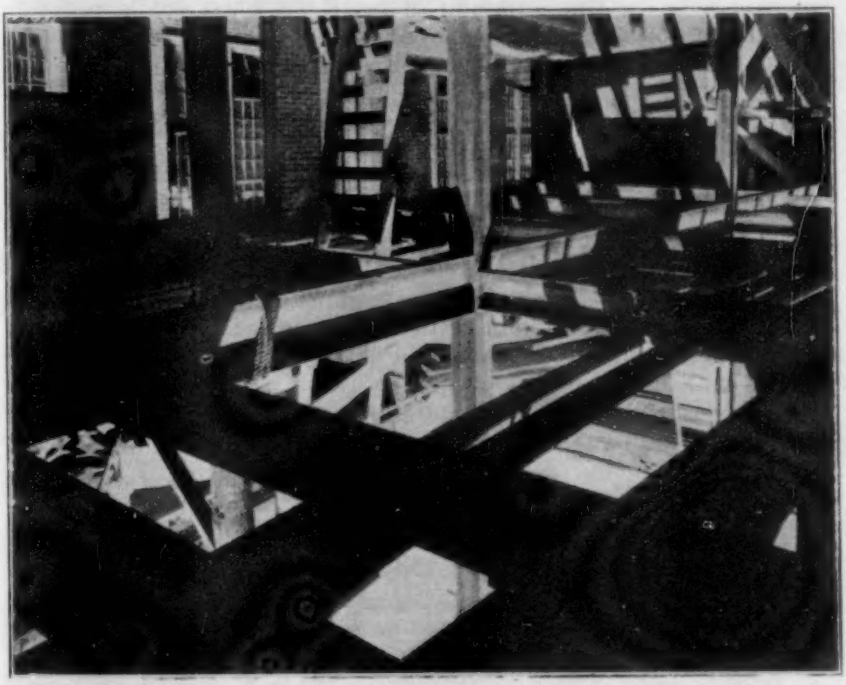
Fig. 2—Close-up of adding addition to new building with the aid of welding





Figs. 3 and 4—External welded frame work for a new elevator pent house in office building





Figs. 5 and 6—Additions of a third floor and 40 ft. length to a two-story brick and steel laboratory building

You all know the difficulty in getting measurements of structures of sufficient accuracy to fabricate new steel to be used in additions or extensions of old structures. This is especially difficult where the old steel is bricked or concreted in.

It is our present practice to make up a bill of material from drawings and purchase the steel cut to length. The steel is delivered directly to the shop and the carpenters and welders do the complete erection. Any necessary cutting to correct for variations in the dimensions as found after steel is uncovered can be taken care of by the cutting brick with very little additional trouble.

Our operators are carpenters who have been given two or three months training in our welding school. They are, therefore, equipped to do welding or carpenter work as required. The average job requires that one-third the number of men on the erecting job should be welders in order to efficiently use the other two-thirds. We estimate that we save one-third of the drawing room time by eliminating the detailing, and from 10 per cent to 20 per cent of the complete job. I believe this to be a conservative estimate, as hold-ups are almost entirely cut out. A resourceful foreman can take care of conditions as he finds them.

The attached photographs show some of the jobs done. Figs. 1 and 2 show the addition of two bays to an existing building. You will note the small amount of brick work cut out in order to make the connections to the old columns.

Figs. 3 and 4 show the external frame work for a new elevator pent house on our office building. Even more new steel is inside the old roof. This job went ahead with absolutely no delays.

Figs. 5 and 6 show portions of the additions of a third floor and 40 ft. in length to a two-story brick and steel laboratory building. The building and extension is of a flatiron type making irregular steel connections numerous.

Some clip angles are, of course, necessary for lining up the work. These are welded to the supporting member and the necessary bolt hole is burned in the beam with the torch. In case or purlins small spacing clips are welded to the top of the truss against which the purlins are placed before welding.

The smoothness and promptness of the completion of these and many other jobs have convinced us that the welding art has become a great time and money saver in maintenance work.

CURRENT WELDING LITERATURE

Aircraft Welding Rigidly Inspected. R. K. Doran. The Welding Engineer (October, 1927), Vol. 12, No. 10, pp. 32-33. A study of the welding organization in a large aircraft plant shows that the high quality of work done is the result of good supervision.

All-Metal Airplane Fuselages. The Iron Age (Oct. 6, 1927), Vol. 120, No. 14, pp. 939-940. Constructed of alloy steel by the army, of plain carbon steel by Stinson, and of Duralumin by Ford.

An Arc Welded Residence. J. G. Dudley. The Welding Engineer (September, 1927), Vol. 12, No. 9, pp. 51-53. A steel framed building with all joints welded, which offers many advantages over other types of building construction.

Arc Welded Building in Berkeley, California. The Welding Engineer (October, 1927), Vol. 12, No. 10, p. 45.

Arc-Welded Wind Bracing Connections. W. A. Haken & R. G. Richards. The Welding Engineer (September, 1927), Vol. 12, No. 9, pp. 40-44. Tests to determine the capacity of a given connection under high bending moments, and to evolve the requisite data for proper design.

Arc Welding Apparatus. C. B. Waters. Canad. Pat. 271748. Pat. Off. Rec. (June 21, 1927) 55. 1421-2.

Arc-Welding Building Costs. Engineering News-Record (Sept. 22, 1927), Vol. 99, No. 12, p. 469.

Arc Welding Device and Method of Operating the Same, Automatic Electric. H. D. Morton. U. S. Pat. 1634624. Off. Gaz. (July 5, 1927) 360. 149.

Correct Arc Length. J. B. Green. The Welding Engineer (October, 1927), Vol. 12, No. 10, pp. 37-38. A study of metal transfer furnishes the basis for determining the proper length and a practical means for maintaining it.

Economical Cutting Metal. The Welding Engineer (September, 1927), Vol. 12, No. 9, pp. 35-37. Some means of mechanical control will increase the efficiency of their operations.

Economy in Arc Welding Practice. Alexander Churchward. The Welding Engineer (September, 1927), Vol. 12, No. 9, p. 53.

Electric Welding. W. R. Hume. Brit. Pat. 267256. Ill. Off. Jnl. (May 4, 1927) 1496.

Electric Welding. J. W. Meadowcroft. Brit. Pat. 268823. Ill. Off. Jnl. (June 1, 1927), 2076.

Electric Welding in Maintenance. J. E. Webster. The Welding Engineer (October, 1927), Vol. 12, No. 10, p. 46.

Electric Welding, Method of. R. Mattice. U. S. Pat. 1634675. Off. Gaz. (July 5, 1927), 360. 159.

Expansion and Contraction of Welded Gas Lines. Engineering News-Record (Oct. 20, 1927), Vol. 99, No. 16, p. 635.

First Arc-Welded Bridge to Be Built. The Welding Engineer (October, 1927), Vol. 12, No. 10, p. 50.

Fusion Welding Pressure Vessels. S. W. Miller. Acetylene Journal (October, 1927), Vol. 29, No. 4, pp. 152-155. Successful results can be obtained in either new work or repair work if proper care is exercised in the selection of methods and materials. Appendix "A." Excerpt from recommendations of Subcommittee on Welding to San Francisco General Committee on Revision of Air Pressure Tank Safety Orders. Outlining control procedure to insure dependable workmanship. Appendix "B." Extracts from discussion of Mr. Miller's paper.

Heavy Current Electrode Holder. Railway Mechanical Engineer (August, 1927), Vol. 101, No. 8, p. 572.

Horizontal Welds on Vertical Plates. D. Richardson. The Welding Engineer (September, 1927), Vol. 12, No. 9, pp. 48-49. Comments on tests that have been made to determine the best preparation of parts and best welding technique.

Limitations of Structural Welding. The Iron Age (Oct. 6, 1927), Vol. 120, No. 14, pp. 943-946. Cheaper if steel shipped from mill to job. Arc welding best for strengthening bridges. Problems confronted by railroad car and automobile builders. Field welding on tall buildings more expensive. Tests of welded wind bracing. Allowable design stresses. Economies in one-story mill buildings. Rust in welded joints. Plant extensions and repairs. Thirteen per cent saved when double-decking Havre de Grace bridge. Welding for railroad car builders.

Manufacture of Welded and Seamless Tubes. H. M. Boylston. The Iron and Steel World (September, 1927), Vol. 1, No. 8, pp. 559-562. Discussion of the lap weld and butt weld with methods of manufacture of tubes; manufacture of seamless tubing; operation of Mannesmann mill and Pilger mill.

Multiple Spot-Welding. Machinery (New York), v. 34, pp. 103-4 (October, 1927). Six welds made simultaneously by the point or projection method.

Oil Industry Keeps Welders Busy. The Welding Engineer (September, 1927), Vol. 12, No. 9, pp. 38-39. The great savings made by welding, for men

who produce and distribute oil products, can be increased by standardizing procedure.

Oxy-Acetylene in the Airplane Industry. Robert K. Doran. Acetylene Journal (October, 1927), Vol. 29, No. 4, pp. 141-143.

Oxy-Acetylene Tips (October, 1927), Vol. 6, No. 3. Oxwelded river crossing. Air brake tanks profitably rebuilt. Bus bodies repaired. Attracting the attention of an entire district. Put your goggles on right. Making the machine fit the shop. Rock products.

Practical Oxy-Acetylene Welding. R. Granjon and others. Welding Journal (September, 1927), Vol. 24, pp. 264-6. Welding of copper vessels built up from sheet copper.

Rational Design of Structural Steel Joints for Arc-Welded Connections. Engr. & Engng. (August, 1927), Vol. 44, pp. 204-11. Elastic limit and other physical tests.

Riveted Steel. A. F. Jensen. Engineers and Engineering (September, 1927), Vol. 44, No. 9, pp. 235-238.

Spot Welding of Dissimilar Metals. R. T. Gillette. The Welding Engineer (September, 1927), Vol. 12, No. 9, pp. 45-47. Uses of spot welding process. Comparison with other methods. Electrode material for dissimilar metals. Electrode shape for unlike thicknesses.

Strengthening Railway Bridge by Electric Welding. Engineer and Contracting (September, 1927), Vol. 46, No. 9, pp. 423-424. How Chicago Great Western R. R. increased capacity of its Leavenworth Bridge described in Railway Age.

Structural Building Stressed at Meeting of Welding Society. Engineering News-Record (Sept. 29, 1927), Vol. 99, No. 13, p. 523.

Structural Welding of Gas Plant, Melbourne, Australia. Engineering News-Record (Oct. 13, 1927), Vol. 99, No. 15, pp. 589-590. Six years of successful construction of welded structural steel work. Design, inspection and checks on performance.

Templets for Pipe Fittings. Acetylene Journal (October, 1927), Vol. 29, No. 4, pp. 144-147. By following these suggestions, patterns for bends, tees and branches can be quickly made. Elements of templet construction. Development of a pipe surface. Templet for 45 deg. intersection. Metal templets. Using the templets. Templets for tees and branches. Making an angle branch.

Testing of Welded Joints—A Preliminary Plan of Research. Eugene Jacobson. Mechanical Engineering (October, 1927), Vol. 49, No. 10, p. 1103.

The "Alternarc" Cutting and Welding Process. The Welding Journal (September, 1927), Vol. 24, No. 288, pp. 270-273.

"The Care of Welding Equipment." V. W. Walker. The Australian Welding Engineer (Sept. 1, 1927), Vol. 1, No. 9, pp. 175-177. Description and conclusions arrived at by the Oxygen Regulator Research Committee of the Compressed Gas Manufacturers' Association on the Investigation of oxygen regulator seat materials.

The Cutler-Marsden Automatic Arc Welding Machines. The Australian Welding Engineer (Sept. 1, 1927), Vol. 1, No. 9, pp. 171-174.

Variety of Uses for the Welding Torch in the Oil Fields. Acetylene Journal (October, 1927), Vol. 29, No. 4, pp. 160-161.

Welded Piping for Every Purpose. The Welding Engineer (October, 1927), Vol. 12, No. 10, pp. 39-41. Elimination of mechanical joints results in economy of installation, increased efficiency and longer life for pipe installations.

Welded Press Has 1000-Ton Capacity. The Welding Engineer (October, 1927), Vol. 12, No. 10, pp. 29-31. Old ideas of using Cast C-Frames entirely abandoned. New type welded steel frame shows 66 per cent saving in cast.

Welding Facts and Figures—XVII. D. Richardson and E. W. Birch. The Welding Journal (September, 1927), Vol. 24, No. 288, pp. 267-269. Handbook for welding engineers.

Welding in the Design of Steel Plate Work. L. J. Sforzini. Acetylene Journal (October, 1927), Vol. 29, No. 4, pp. 156-157. Simplicity is a strong factor in favor of substituting welding for other methods of fabrication. Examples of welded jobs that have reduced construction costs.

Welding Pipe Line in Long Sections Facilitates Testing and Installation. Acetylene Journal (October, 1927), Vol. 29, No. 4, pp. 158-159.

Welding Pure Aluminum—Flux and Operation Requirements. Engineering News-Record (Sept. 29, 1927), Vol. 99, No. 13, p. 519.

Welding Steel Window Frames. Engineering and Contracting (September, 1927), p, 432, Vol. 46, No. 9.

Training Courses for Gas, Resistance and Thermit Welding Now Ready

These bulletins have been compiled by the Educational Committee of the American Welding Society and embody useful fundamental information for student welders and welding engineers. Knowledge of the substance of these courses insures a grasp of the fundamentals of welding. Price per bulletin for Gas Course, 50c, Resistance Course, 35c, and Thermit Course, 50c.

Special prices for quantity lots of 100 or more.

AMERICAN WELDING SOCIETY
29 West 39th Street
New York, N. Y.

TORCHWELD LEADERSHIP

"Standard of Comparison"

Torchweld is the acknowledged leader in the gas welding and cutting equipment field because Torchweld design is original and Torchweld superior construction insures long and satisfactory service.

TORCHWELD EQUIPMENT CO.

224 No. Carpenter St. Chicago, Ill.

The Trade Knows What

means on

Welding and Cutting Equipment

K-G WELDING & CUTTING CO., Inc.

515 West 29th Street

Phone Chickering 0996-7-8 New York City

Strong Welds

The efficiency of welding in repairing broken machine parts; in bonding rails; joining structural steel; and countless other uses in the industrial fields, has been definitely proven. To give satisfactory service, the wire must be strong, tough, uniform, and give the least trouble in welding. All of these qualities are found in Roebling Welding Wire

JOHN A. ROEBLING'S SONS COMPANY

Trenton N. J.

Roebling Welding Wire

Before you settle on the type of machine— get the users viewpoint

Any Lincoln office below will put you in touch with a user near you whose experience covers many types of welders. Get his viewpoint based on experience.

They say

(a new list in each issue)

"The machine effects a yearly saving of approximately $5,000."

* * *

"We do not believe there is a better article made than the Lincoln machine and we have several of them in use in our plant."

* * *

"Saving of this machine is 100 percent on current, besides the high cost of general repair jobs if it wasn't for this machine."

* * *

"We have three Lincoln welders. They are used on tanks, stacks and steel plate construction work. We believe that electric welding saves 50 percent over the riveting."

LINCOLN "Stable Arc" WELDER

Branch Offices
Baltimore
Boston
Buffalo
Charlotte, N. C.
Chicago
Cincinnati
Detroit
Grand Rapids

The Lincoln Electric Co.

General Offices and Factory:
Cleveland, Ohio

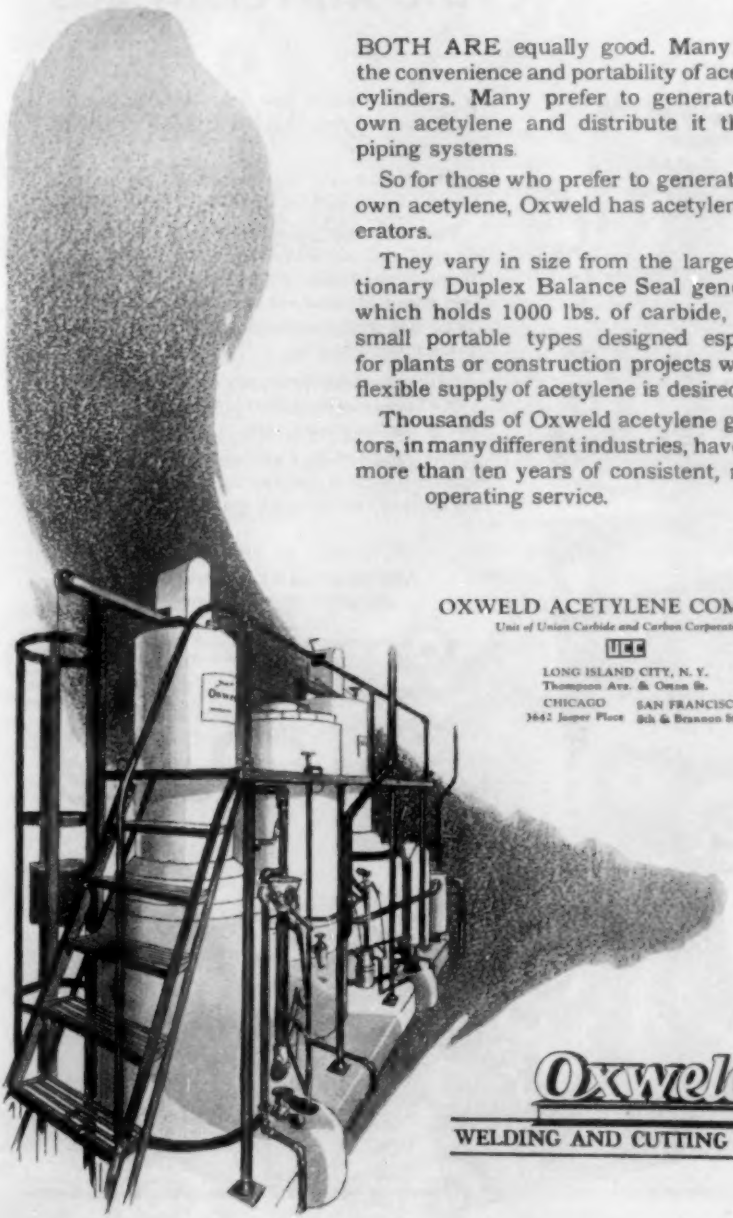
Branch Offices
Kansas City
Lancaster
Milwaukee
Minneapolis
New York City
Philadelphia
Pittsburgh
Syracuse

The Lincoln Electric Co. of Canada, Ltd., Toronto-Montreal

Distributing agencies in all principal cities.

Exclusive Agencies with Stock:
Portland, Ore. Seattle Los Angeles
New Orleans Atlanta San Francisco

Dissolved or generated acetylene?



BOTH ARE equally good. Many prefer the convenience and portability of acetylene cylinders. Many prefer to generate their own acetylene and distribute it through piping systems.

So for those who prefer to generate their own acetylene, Oxweld has acetylene generators.

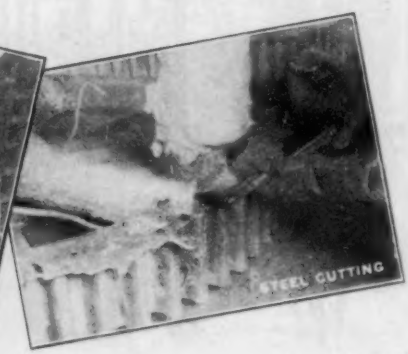
They vary in size from the largest stationary Duplex Balance Seal generator, which holds 1000 lbs. of carbide, to the small portable types designed especially for plants or construction projects where a flexible supply of acetylene is desired.

Thousands of Oxweld acetylene generators, in many different industries, have given more than ten years of consistent, reliable operating service.

OXWELD ACETYLENE COMPANY
Unit of Union Carbide and Carbon Corporation
UCC
LONG ISLAND CITY, N. Y.
Thompson Ave. & Orton St.
CHICAGO
3642 Jasper Place
SAN FRANCISCO
8th & Brannan Sts.

Oxweld
WELDING AND CUTTING APPARATUS

Acetylene—
the universal gas



OCCASIONALLY one hears of a gas other than acetylene that can be used with oxygen for cutting steel.

The promoters of such gases readily admit that acetylene is the best for all other uses with oxygen.

That's why acetylene can be called the universal gas for all oxy-acetylene welding and cutting. It can be used equally well for welding thick or thin plates of metal. It is the most satisfactory for cutting steel or cast iron, and also for brazing, welding and soldering.

In fact, the very term—*oxy-acetylene* process—itself is a good indication of the fact that acetylene is the "universal" gas.

The Prest-O-Lite Company has 31 plants in operation and 101 distributing points for supplying users of this universal gas.

THE PREST-O-LITE COMPANY, INC.
Unit of Union Carbide and Carbon Corporation
UCC
General Offices: Carbide and Carbon Building
30 East 42d St., New York
31 Plants—101 Warehouses

Prest-O-Lite

Oxwelding has introduced sheet metal to the engineer*

ENGINEERS well remember the day when sheet metal equipment was put together with riveted or locked-seam joints. They were either unsightly or flimsy.

Now it is a different story. With high test steel welding rods it is possible to make sheet metal joints that are stronger than the metal itself. This rigid, durable flush type of joint has found wide acceptance in many industries, not only because of its strength but because of its ability to take and hold a finish of baked enamel.

Modern iceless refrigerators, where permanently tight joints are essential, are possible because of the oxwelded joint. The construction of ventilating ducts has been greatly simplified by the flexibility of the oxwelding process. And their effectiveness is increased tremendously because oxwelded joints do not leak.

In the building of automobile bodies and aircraft fuselages, where strength and dependability are vital, are two modern applications of oxy-acetylene welding to sheet metal construction. The strength and finish of the oxwelded joint are more largely responsible than any single thing for the wider use of sheet metal in engineering construction.

Linde engineers have much valuable information on the use of the oxy-acetylene process in sheet metal construction. This information is available upon request.

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
UCC
General Offices: Carbide and Carbon Building
30 East 42d Street, New York
32 PLANTS . . . . . 105 WAREHOUSES

LINDE OXYGEN

* No. 11 of a series of advertisements on the engineering phases of oxy-acetylene welding and cutting. Send for the booklet entitled: "Engineering and Management Phases of Oxwelded Construction."

Returned to Service at a saving in time and labor

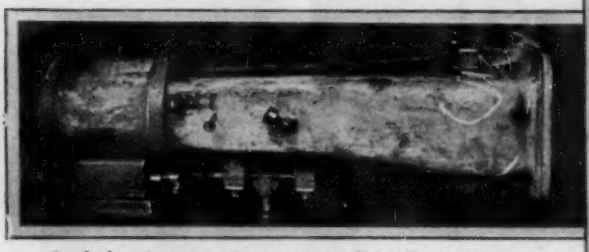
TOBIN Bronze Welding by the oxy-acetylene process made it possible to return this cracked engine casting to service as strong as ever in two hours and a half.

Because Tobin Bronze flows freely at 1650°F., complete dismantling for preheating in a furnace was unnecessary. The low temperature used also prevented distortion of the casting.

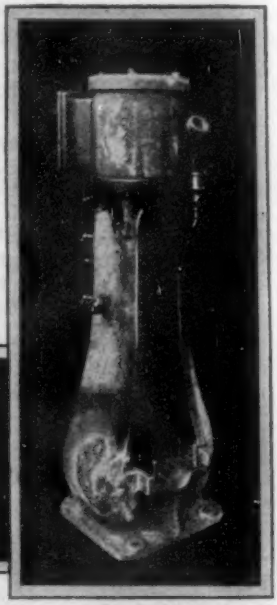
The great strength of the welds, together with the saving in time effected by the elimination of extensive preheating, makes Tobin Bronze Welding the logical method for many production operations as well as for repairs.

Tobin Bronze, manufactured exclusively by The American Brass Company, may be obtained from leading distributors of welding equipment and supplies.

THE AMERICAN BRASS COMPANY
General Offices: WATERBURY, CONNECTICUT
Canadian Mill: ANACONDA AMERICAN BRASS LIMITED
New Toronto, Ontario



Cracked engine casting in position for Tobin Bronze Welding



As repaired with Tobin Bronze by the Oxy-Acetylene Process

TOBIN BRONZE
REG. U.S. PAT. OFF.
WELDING RODS
EXCLUSIVELY AN ANACONDA PRODUCT

One of two welding sets used by the Southern Pacific Railroad

The G-E Portable Arc Welder for Track Maintenance

Builds up battered rail ends
Reclaims manganese track work

General Electric furnishes to the Welding Industry:

WD Arc Welders—designed for one operator
Constant Potential Sets—for several operators
Arc Welding Resistors—for mining and traction companies
Automatic Sets—for repetition work

Complete information and bulletins available at your nearest G-E office.

"New track work for old" follows the path of this magic wand. Traveling along the main line or branch lines, this welder builds up battered rail ends; reclaims manganese switch points, frogs, and crossings; bonds rails; repairs leaky water pipes and towers; welds metal culverts, crossing gate supports, and safety devices.

As a typical example, the "Milwaukee" railroad reclaimed a $1200 manganese crossover for $200.

Your nearest G-E office will provide you with detailed information as to this remarkable investment.

530-25D

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK

ACETYLENE IN PORTABLE CYLINDERS FOR OXY-ACETYLENE WELDING AND CUTTING

Do you understand our free loan cylinder plan? If not, we are glad to explain

Supplied in the following size cylinders:

10" x 30"—capacity 125 cu. ft.
12" x 36"— " 225 " "
12" x 44"— " 275 " "

Prompt and efficient service on any quantity through plants and warehouses and truck deliveries.

Commercial Acetylene Supply Co., Inc.

(Main Office) 71 Broadway, New York City, N. Y.

BRANCHES:
613 Trust Co. of Georgia Bldg., Atlanta, Ga.
80 E. Jackson Boulevard, Chicago, Ill.
553 Monadnock Bldg., San Francisco, Cal.

SWEDOX

WELDING RODS, WIRES and ELECTRODES

A Grade for Every Purpose

NONOX SWEDOX
LEKTROX SWEDOX
CASTOX
ARC CARBOX
GAS CARBOX
VANOX

TENSKOTE
DUCTKOTE
DUCTILOX
NICKOX
RAILOX

BRONZOX
BRONZKOTE
TOBIN BRONZE
MANGANESE BRONZE
MONEL METAL

STEELKOTE
LEKKOTE
CYLKOTE
MANKOTE
RAILKOTE

KROMOX
MANGANOX
ALUMINOX
DRAWN ALUMINUM
BRAZOX

TENSILOX
KROMKOTE
NICKOTE
VANKOTE
FLUXES

SEND FOR TESTING SAMPLE

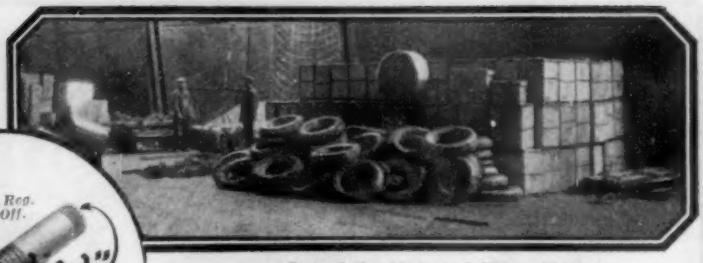
We want every welder in the country—big or small—to be convinced of the *specialized superiorities* of SWEDOX products. We know that a trial *will* convince you. Hence the free offer. Try SWEDOX on your next welding job at our expense.

CHICAGO, ILL.
4545 S. Western Blvd.
Phone:
LaFayette 8500

Central Steel & Wire Company

DETROIT, MICH.
5001 Bellevue Ave.
Phone:
Lincoln 6780

"We Ship the Same Day"



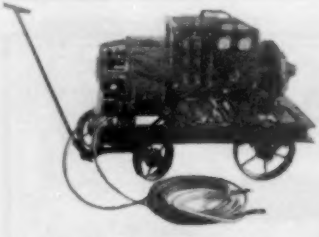
Part of the 40 tons of Wilson Welding Wire awaiting shipment to Manchuria, China, for the Baldwin Locomotive Works.

Trade Mark Reg. U. S. Pat. Off.

"Color-tipt"

Insisted Upon *for* Repairs *in* Far-Away China

A large trans-continental railway in Northern Manchuria was recently faced with a series of vital repair jobs—so far away that the welding wire selected had to be absolutely dependable. They knew from long experience that they could trust Wilson "Color-tipt" Welding Wire anywhere, and forty tons were sent in one shipment to Manchuria.



The above is a Wilson Type S Single-Operator Motor Driven Electric Welding Machine — designed for both production and repair work, and adapted for use wherever power is available. Its capacity is 25 to 300 amperes. Other Type S Machines include both single and two-operator units — gasoline-engine-driven, belt-driven and motor-driven—portable and stationary. Capacities: 25-250, 25-300, 25-600 amperes.

In every part of the world—in practically every industry—you will find Wilson Wire used where enduring strength in a weld is essential. Yet the superiority and economy of Wilson Wire are not confined to welds of paramount importance. After all, any welding worth doing is worth doing **right.** That requires perfect uniformity in the welding wire. And that is what Wilson Wire is noted for.

Every grade (analysis) of Wilson Wire runs uniform throughout—every rod is just like every other rod of the same grade. And there is a grade for each kind of metal—for the particular metal you are welding—for your particular industry. Each grade is designated by a color.

Write today for a sample of Wilson Wire—just indicate the kind of welding you wish to do. Also, ask for bulletins describing Wilson Welding Machines.

WILSON WELDER & METALS CO. INC., WILSON BLDG., HOBOKEN, NEW JERSEY

WILSON

WELDING MACHINES AND WELDING WIRE

Training Courses for Welders

Now Ready

Gas Course	50c per copy
Electric Arc Course	50c per copy
Resistance Course	35c per copy
Thermit Course	50c per copy

AMERICAN WELDING SOCIETY

NATIONAL CARBIDE

for

House Lighting and Cooking

Miners Lamps and other Carbide Lamps

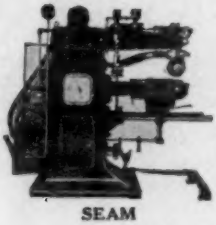
Oxyacetylene Welding and Cutting

In the RED DRUM

Saves You Money

NATIONAL CARBIDE SALES CORPORATION, 342 Madison Ave., N.Y.

SPOT



SEAM

ARC

For Production
Electric Welding
Machines

Gibb Welding Machines Company

Bay City, Michigan

New York—Philadelphia—Cleveland—Cincinnati—Detroit—Buffalo
Chicago—St. Louis—Los Angeles—Toronto—Montreal

Weldite

Welding Rod

WELDITE G—No. 6 Coppered Finish for gas welding lays the metal down quietly, free from boiling, free from surface scum and floating white specks. The metal settles instantly when the torch is removed.

WELDITE E—No. 18 Green Surfaced for electric welding is the smoothest running electrode ever offered users of welding. Sold at the price of bare electrodes.

Products of the Research Department

MANUFACTURED BY

CHICAGO STEEL & WIRE CO

103rd Street *and* Torrence Avenue CHICAGO

THERMIT

1902 — Twenty-five Years — 1927

Our engineering organization starting with a scientifically correct principle twenty-five years ago has developed the Thermit process to its present highly efficient state.

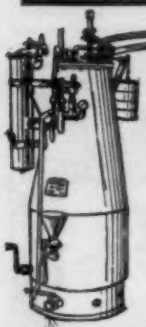
Today it is inexpensive, proven, practical and simple in its application to all classes of work involving the repair of medium and heavy size sections of iron and steel.

WELDING

Metal & Thermit Corporation

120 Broadway, New York

Pittsburgh Chicago Boston S. San Francisco Toronto



Why Experiment?

Torches
Regulators
Generators
Compressors
Manifolds
Preheaters
Paint Sprays
Carbide Lights

Catalog 54?

SINCE the infancy of the industry, expert engineers and skilled workmen have maintained the predominance of Milburn Equipment.

Its acceptance as standard equipment by large industrials, railroads and Government Departments the world over exemplifies Milburn leadership.

THE ALEXANDER MILBURN CO.
Baltimore, Md.

If You Want to Know Why

REGO

OXY-ACETYLENE EQUIPMENT

Gives more satisfactory service. Operates with a lower gas cost. Costs less to maintain *than any other equipment—*

Write for Booklet - "FACTS"

THE BASTIAN-BLESSING CO.

252 E. Ontario St. -:- Chicago

When every weld must *grip*

like every other weld

Give the man on the job Page Welding Wire and Electrodes and you can be sure every weld is a good weld.

For Page Welding products are produced to help workmen get better results. Every rod is plainly marked with name and grade and the bundle carries a distinctive tag—there is no guesswork.

Large stocks are carried by our distributors at convenient shipping points. Every wire is carefully processed and shop tested for actual performance.

A request brings samples.

PAGE STEEL AND WIRE COMPANY

Bridgeport Connecticut

An Associate Company of the American Chain Company, Inc.

District Offices: Chicago, New York, Pittsburgh, San Francisco.

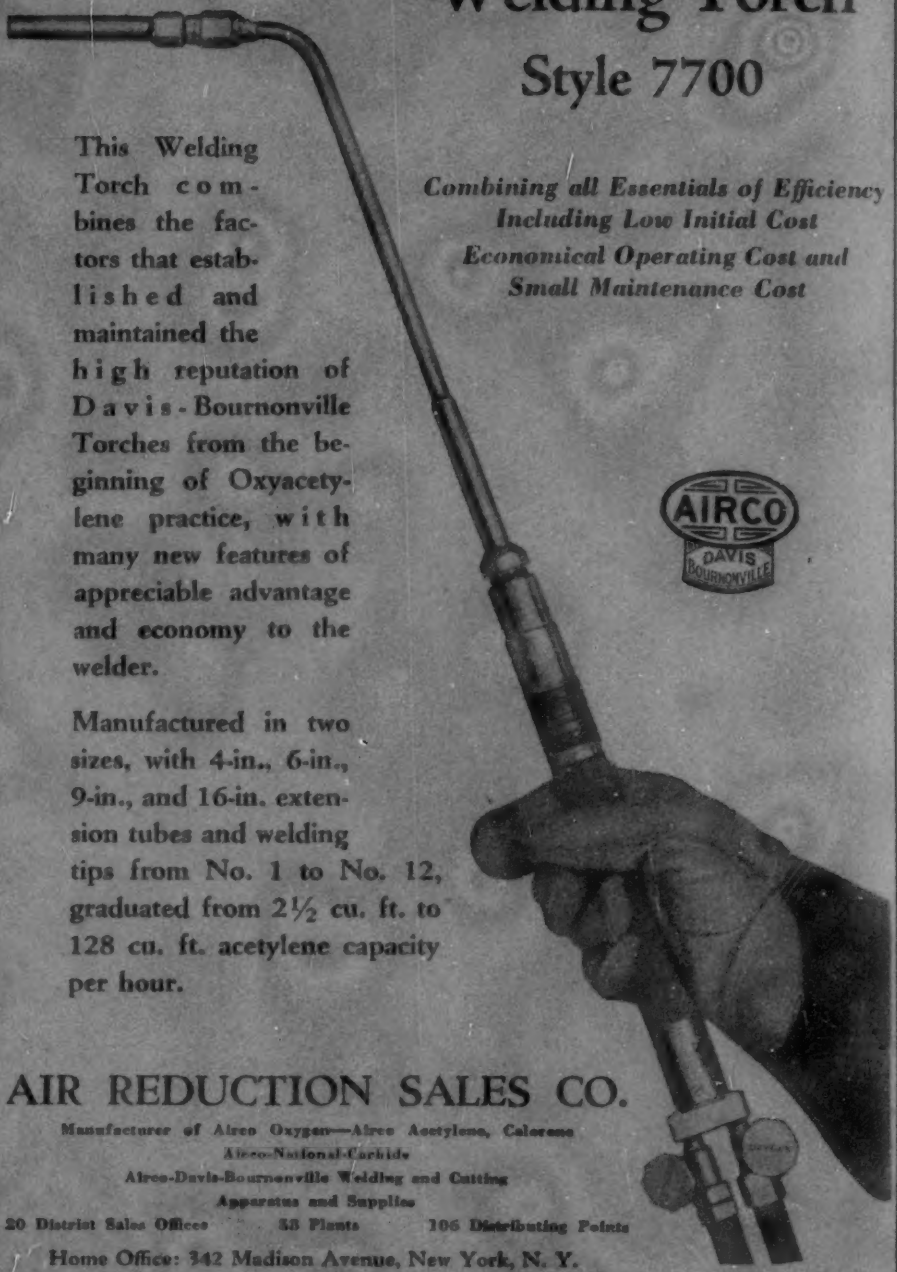
PAGE-ARMCO PROCESSED

Welding Wire *and* Electrodes

An Airco-Davis-Bournonville

Welding Torch

Style 7700



Combining all Essentials of Efficiency
Including Low Initial Cost
Economical Operating Cost and
Small Maintenance Cost

This Welding Torch combines the factors that established and maintained the high reputation of Davis-Bournonville Torches from the beginning of Oxyacetylene practice, with many new features of appreciable advantage and economy to the welder.

Manufactured in two sizes, with 4-in., 6-in., 9-in., and 16-in. extension tubes and welding tips from No. 1 to No. 12, graduated from 2½ cu. ft. to 128 cu. ft. acetylene capacity per hour.

AIR REDUCTION SALES CO.

Manufacturer of Airco Oxygen—Airco Acetylene, Calorene
Airco-National-Carbide
Airco-Davis-Bournonville Welding and Cutting
Apparatus and Supplies

20 District Sales Offices 35 Plants 106 Distributing Points

Home Office: 342 Madison Avenue, New York, N. Y.